

E. Eng.
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CONDENSED PROGRAM

National Metal Congress and Exposition

Cleveland, Ohio, Feb. 4 to 8, 1946

Monday, Feb. 4, 1946

- 9:30 A.M. Technical Session on Aluminum Alloys; Lattice Room, Hotel Statler.
9:30 A.M. Technical Session on Heat Treatment of Alloy Steels; Grand Ballroom, Hotel Statler.
9:30 A.M. Technical Session on Carburizing and Decarburizing; Euclid Ballroom, Hotel Statler
12:00 M. National Metal Exposition opens; Public Auditorium.
8:30 P.M. Round Table Discussion on Decomposition of Austenite; Music Hall, Public Auditorium.
10:30 P.M. National Metal Exposition closes.

Tuesday, Feb. 5, 1946

- 9:30 A.M. Technical Session on Research; Euclid Ballroom, Hotel Statler.
9:30 A.M. Technical Session on Stresses in Metals; Grand Ballroom, Hotel Statler.
9:30 A.M. Technical Session on Non-Ferrous Alloys; Lattice Room, Hotel Statler.
12:00 M. National Metal Exposition opens; Public Auditorium.
2:00 P.M. Technical Session on Chromium and Stainless Steels; Ballroom, Public Auditorium.
2:00 P.M. Technical Session on Quenching of Steels; Clubroom B, Public Auditorium.
8:30 P.M. Round Table Discussion on Super-Alloys for High Temperature Service in Gas Turbines and Jet Engines; Music Hall, Public Auditorium.
10:30 P.M. National Metal Exposition closes.

Wednesday, Feb. 6, 1946

- 10:00 A.M. Edward de Mille Campbell Memorial Lecture, by M. Gensamer; Grand Ballroom, Hotel Statler.
10:00 A.M. Lester Lecture of the American Industrial Radium and X-Ray Society, by O. R. Carpenter; Hollenden Hotel.
12:00 M. National Metal Exposition opens.
2:00 P.M. Technical Session on Inspection; Clubroom B, Public Auditorium.
2:00 P.M. Technical Session on Induction Hardening; Ballroom, Public Auditorium.
2:00 P.M. American Industrial Radium and X-Ray Society Technical Session on Non-Destructive Testing Other Than Radiography; Hollenden Hotel.
8:30 P.M. Round Table Discussion on Atomic Energy and Its Implications ("Nucleonics"); Music Hall, Public Auditorium.
10:30 P.M. National Metal Exposition closes.

Thursday, Feb. 7, 1946

- 9:00 A.M. Lecture on Extractive Metallurgy of Magnesium; Clubroom B, Public Auditorium.
9:00 A.M. Lecture on Principles and Theory of High Frequency Heating; Ballroom, Public Auditorium.
9:00 A.M. Lecture on Surface Stressing — Defining the Problem; Clubroom A, Public Auditorium.

9:00 A.M. Lecture on the Basic Principles of Metallic Corrosion; Clubroom C, Public Auditorium.

10:00 A.M. American Industrial Radium and X-Ray Society Technical Session on X-Ray Diffraction; Hollenden Hotel.

10:00 A.M. National Metal Exposition opens.

10:30 A.M. Lecture on Magnesium Structural Design; Clubroom B, Public Auditorium.

10:30 A.M. Lecture on Induction Heating Circuits and Frequency Generation; Ballroom, Public Auditorium.

10:30 A.M. Lecture on Measurement of Surface Stresses; Clubroom A, Public Auditorium.

10:30 A.M. Lecture on Effect of Composition and Environment on Corrosion of Iron and Steel; Clubroom C, Public Auditorium.

2:00 P.M. American Industrial Radium and X-Ray Society Technical Session on Radiographic Inspection; Hollenden Hotel.

4:30 P.M. Lecture on Magnesium Castings; Clubroom B, Public Auditorium.

4:30 P.M. Lecture on Practical Applications of the Motor-Generator Type of Induction Heating (Frequencies up to 10,000 Cycles); Ballroom, Public Auditorium.

4:30 P.M. Lecture on Tests for Surface Stressing, Including Carburizing and Nitriding; Clubroom A, Public Auditorium.

4:30 P.M. Lecture on Corrosion Resistance of Stainless Steels and High Nickel Alloys; Clubroom C, Public Auditorium.

6:00 P.M. National Metal Exposition closes.

7:30 P.M. Annual Banquet of the A.S.M.; Hotel Statler.

Friday, Feb. 8, 1946

9:00 A.M. Lecture on Wrought Magnesium Alloy Fabrication; Clubroom B, Public Auditorium.

9:00 A.M. Lecture on Practical Applications of High Frequency Induction Heating (100,000 Cycles and Up); Ballroom, Public Auditorium.

9:00 A.M. Lecture on Stressing Axles and Other Railroad Equipment by Cold Rolling; Clubroom A, Public Auditorium.

9:00 A.M. Lecture on Corrosion of Aluminum and Magnesium; Clubroom C, Public Auditorium.

10:00 A.M. American Industrial Radium and X-Ray Society and A.S.T.M. Joint Symposium on Ultra High Voltage and High Speed Radiography; Hollenden Hotel.

10:00 A.M. National Metal Exposition opens.

10:30 A.M. Lecture on Corrosion and Protection of Magnesium; Clubroom B, Public Auditorium.

10:30 A.M. Lecture Comparing Induction Heating With Other Methods of Heat Treating; Ballroom, Public Auditorium.

10:30 A.M. Lecture on Progressive Stress Damage; Clubroom A, Public Auditorium.

10:30 A.M. Lecture on Copper and Copper Alloys in Corrosive Environments; Clubroom C, Public Auditorium.

2:00 P.M. American Industrial Radium and X-Ray Society and A.S.T.M. Joint Symposium on Ultra High Voltage and High Speed Radiography; Hollenden Hotel.

6:00 P.M. National Metal Exposition closes.



Technical Meetings



Monday, February 4

Simultaneous Morning Sessions—9:30 A.M.

Aluminum Alloys

LATTICE ROOM, HOTEL STATLER

Drawability of Aluminum Alloys at Elevated Temperatures. Part I—Deep Drawing Cylindrical Cups, by *D. M. Finch, S. P. Wilson and J. E. Dorn*, University of California.

Deep Drawing Aluminum Alloys at Elevated Temperatures. Part II—Deep Drawing Boxes, by *D. M. Finch, S. P. Wilson and J. E. Dorn*, University of California.

New Aluminum Alloys Containing Small Amounts of Beryllium, by *R. H. Harrington*, General Electric Co.

Heat Treatment of Alloy Steels

*GRAND BALLROOM, HOTEL STATLER

The Partition of Molybdenum in Hypo-Eutectoid Iron-Carbon-Molybdenum Alloys, by *Fred E. Bowman*, Climax Molybdenum Co.

The Effect of Variations in Composition and Heat Treatment on Some Properties of 4 to 6% Chromium Steel Containing Molybdenum and Titanium, by *Geo. F. Comstock*, Titanium Alloy Mfg. Co.

Iron-Manganese Alloys—the Properties of Cold Worked and Heat Treated Alloys Containing 1 to 7% Manganese, by *R. S. Dean, J. R. Long, T. R. Graham and R. G. Feustel*, Bureau of Mines.

Carburizing and Decarburizing

EUCLID BALLROOM, HOTEL STATLER

The Application of Ms Points to Case Depth Measurement, by *E. S. Rowland and S. R. Lyle*, Timken Roller Bearing Co.

A Mechanism of the Surface Decarburization of Steel, by *W. A. Pennington*, Carrier Corp.

Graphite in Cold Rolled Subcritically Annealed Hypo-Eutectoid Steels, by *M. A. Hughes and J. G. Cutton*, Carnegie-Illinois Steel Corp.

Tuesday, February 5

Simultaneous Morning Sessions—9:30 A.M.

Research

EUCLID BALLROOM, HOTEL STATLER

High Forging Temperatures Revealed by Facets in Fracture Tests, by *J. Robert Strohm and W. E. Jominy*, Chrysler Corp.

Critical Points of SAE 4340 Steel as Determined by the Dilatometric Method, by *D. Niconoff*, Republic Steel Corp.

Gas Evolution From Cast Steel at Room Temperature, by *H. H. Johnson, L. H. Arner and H. A. Schwartz*, National Malleable & Steel Castings Co.

Stresses in Metals

GRAND BALLROOM, HOTEL STATLER

The Effects of Combined Stresses and Low Temperatures on the Mechanical Properties of Some Non-Ferrous Metals, by *D. J. McAdam, Jr., G. W. Geil and R. W. Mebs*, National Bureau of Standards.

Temper Brittleness, by *John H. Hollomon*, Watertown Arsenal.

Fracture of Metals Under Combined Stresses, by *D. J. McAdam, Jr.*, National Bureau of Standards.

Non-Ferrous Alloys

LATTICE ROOM, HOTEL STATLER

Soft Soldering, by *M. E. Fine and R. L. Dowdell*, University of Minnesota.

The Cold Working and Heat Treatment of a 10-Karat Gold Alloy, by *Vernon H. Patterson and B. N. Iannone*, Bausch & Lomb Optical Co.

Tellurium in the Iron Foundry, by *James O. Vadeboncoeur*, General Motors Corp.

Simultaneous Afternoon Sessions—2 P.M.

Chromium and Stainless Steels

BALLROOM, PUBLIC AUDITORIUM

Investigation of a Type of Failure of 18-8 Stabilized Stainless Steel, by *W. C. Kahn, H. Oster and R. Wachtell*, Republic Aviation Corp.

The Influence of Carbon Content Upon the Transformations in 3% Chromium Steel, by *Taylor Lyman, Bendix Aviation Corp., and A. R. Troiano*, University of Notre Dame.

Effect of Nickel on Physical Properties and Thermal Characteristics of Some Cast Chromium-Molybdenum Steels, by *N. A. Ziegler and W. L. Meinhardt*, Crane Co.

Quenching of Steels

CLUBROOM B, PUBLIC AUDITORIUM

Factors Affecting the Hardenability of Boron-Treated Steels, by *R. A. Grange and T. M. Garvey*, U. S. Steel Corp. Research Laboratories.

Quenching of Steel Balls and Rings, by *Victor Paschkis*, Columbia University.

Mass Temperature Effects on Quenching 36% Cobalt Magnet Steel, by *Benjamin Falk*, Simonds Saw & Steel Co.

Wednesday, February 6

Campbell Memorial Lecture—10 A.M.

GRAND BALLROOM, HOTEL STATLER

Edward de Mille Campbell Memorial Lecture, by *M. Gensamer*, Pennsylvania State College.

Simultaneous Afternoon Sessions—2 P.M.

Inspection

CLUBROOM B, PUBLIC AUDITORIUM

Anti-Reflection Films for Metallographic Objectives, by *James R. Benford*, Bausch & Lomb Optical Co.

Detection, Causes and Prevention of Injury in Ground Surfaces, by *L. P. Tarasov*, Norton Co.

The Practical Application of Statistical Methods in a Quality Control Program, by *W. T. Rogers*, National Tube Co.

Induction Hardening

BALLROOM, PUBLIC AUDITORIUM

Stress Comparisons by Correlation With High Frequency Magnetic and Eddy Current Losses, by *P. E. Cavanagh*, Allen B. DuMont Labs.

Metallurgical Characteristics of Induction-Hardened Steel, by *James W. Poynter*, Army Air Forces, Wright Field.

Induction Hardening and Austenitizing Characteristics of Several Medium Carbon Steels, by *D. L. Martin*, General Electric Co., and *W. G. Van Note*, North Carolina State College.



Round Tables and Lectures



THREE round table discussions, modeled after the plan used by the University of Chicago in its regular Sunday broadcasts, are scheduled for the first three evenings of the week. Each will be held at 8:30 P. M. in Music Hall of Public Auditorium, under ideal conditions for both the panel and the audience. The subjects are of great importance; discussions will be quite extemporaneous; each panel consists of experts.

Monday, Feb. 4; 8:30 P.M.

Decomposition of Austenite

Chairman—*Capt. J. H. Hollomon*, Ordnance Department, Watertown Arsenal.

Panel Members—*Robert F. Mehl*, head, department of metallurgy, Carnegie Institute of Technology.

Clarence Zener, Institute for the Study of Metals, University of Chicago.

W. H. Brandt, assistant manager, materials engineering department, Westinghouse Electric Corp.

E. S. Davenport, assistant to vice-president, United States Steel Corp.

Morris Cohen, department of metallurgy, Massachusetts Institute of Technology.

Tuesday, Feb. 5; 8:30 P.M.

Super-Alloys for High Temperature Service in Gas Turbines and Jet Engines

Chairman—*C. T. Evans, Jr.*, chief metallurgist, Elliott Co.

Panel Members—*Howard Cross*, Battelle Memorial Institute.

Russell Franks, chief metallurgist, Union Carbide and Carbon Research Laboratories.

N. L. Mochel, metallurgical engineer, Westinghouse Electric Corp.

Gunther Mohling, research metallurgist, Allegheny Ludlum Steel Corp.

W. L. Badger, metallurgical section, Thomson Laboratory, General Electric Co.

F. S. Badger, metallurgist, Haynes Stellite Co.

Wednesday, Feb. 6; 8:30 P.M.

Atomic Energy and Its Implications ("Nucleonics")

Chairman—*Cyril Stanley Smith*, head of metallurgy division, Los Alamos laboratory of Manhattan Engineer District, and director of Metals Institute, University of Chicago.

Panel Members—*S. K. Allison*, Institute of Nuclear Studies, University of Chicago.

Zay Jeffries, vice-president, General Electric Co.

A. B. Kinzel, vice-president, Union Carbide and Carbon Research Laboratories.

John Chipman, director of M.I.T. Metallurgical Project, and professor of metallurgy, Massachusetts Institute of Technology.

FOUR lecture courses of five lectures each are scheduled for Thursday (9, 10:30 and 4:30) and Friday (9 and 10:30) at the Public Auditorium. Each will be held in its own room, and the subjects discussed by men who are leaders in that branch of metallurgy.

On Magnesium

All held in Clubroom B, Public Auditorium

Lecture 1: **Extractive Metallurgy**, by *L. M. Pidgeon*, University of Toronto.

Lecture 2: **Magnesium Structural Design**, by *J. C. Mathes*, Dow Chemical Co.

Lecture 3: **Castings**, by *N. E. Woldman*, Bendix Aviation Corp.

Lecture 4: **A Survey of Wrought Magnesium Alloy Fabrication**, by *J. V. Winkler*, Dow Chemical Co.

Lecture 5: **Corrosion and Protection of Magnesium**, by *W. S. Loose*, Dow Chemical Co.

On Induction Heating

All held in Ballroom, Public Auditorium

Lecture 1: **Principles and Theory of High Frequency Heating**, by *H. B. Osborn, Jr.*, Ohio Crankshaft Co.

Lecture 2: **Induction Heating Circuits and Frequency Generation**, by *P. H. Brace*, Westinghouse Electric Corp.

Lecture 3: **Practical Applications of the Motor-Generator Type of Induction Heating (Frequencies up to 10,000 Cycles)**, by *W. G. Johnson*, Caterpillar Tractor Co.

Lecture 4: **Practical Applications of High Frequency Induction Heating (100,000 Cycles and Up)**, by *J. W. Cable*, Induction Heating Corp.

Lecture 5: **A Comparison of Induction Heating to Other Methods of Heat Treating**, by *T. E. Eagan*, Cooper-Bessemer Corp.

On the Effect of Surface Stressing on Endurance of Metals

All held in Clubroom A, Public Auditorium

Lecture 1: **The Problem Defined**, by *H. F. Moore*, University of Illinois.

Lecture 2: **Measurement of Surface Stresses**, by *W. M. Murray*, Society for Experimental Stress Analysis.

Lecture 3: **Methods of Applying and Tests Used; Including Carburizing and Nitriding**, by *J. O. Almen*, General Motors Corp.

Lecture 4: **Stressing Axles and Other Railroad Equipment by Cold Rolling**, by *O. J. Horger*, Timken Roller Bearing Co.

Lecture 5: **Progressive Stress Damage**, by *Peter R. Kosting*, Watertown Arsenal.

On Corrosion of Metals

All held in Clubroom C, Public Auditorium

Lecture 1: **Basic Principles of Metallic Corrosion**, by *Carl W. Borgmann*, University of Colorado.

Lecture 2: **Effect of Composition and Environment on Corrosion of Iron and Steel**, by *C. P. Larabee*, Carnegie-Illinois Steel Corp.

Lecture 3: **Corrosion Resistance of Stainless Steels & High Nickel Alloys**, by *W. O. Binder*, Union Carbide and Carbon Research Laboratories.

Lecture 4: **Corrosion of Light Metals**, by *E. H. Dix, Jr.*, Aluminum Co. of America.

Lecture 5: **Copper and Copper Alloys in Corrosive Environments**, by *H. L. Burghoff*, Chase Brass & Copper Co.

Exhibitors at National Metal Exposition

- Aberdeen Chamber of Commerce, Aberdeen, Wash., Booth F604
 Ace Abrasive Laboratories, New York City, Booth G605
 Agaloy Tubing Co., Springfield, O., Booth D330
 A.I.M.E.S. Engineering Co., Cleveland, Booth D744
 Air Hydraulics, Inc., Chelsea, Mich., Booth K631
 Air Reduction Sales Co., New York City, Booth D621
 Akron Bronze & Aluminum Co., Akron, O., Booth F110
 Allegheny Ludlum Steel Corp., Brackenridge, Pa., Booth B410
 Allen Mfg. Co., Hartford, Conn., Booth B142
 Allis-Chalmers Mfg. Co., Milwaukee, Wis., Booth C603
 Allison Co., Bridgeport, Conn., Booth D315
 Alloy Casting Co., Champaign, Ill., Booth C113
 Alox Corp., Niagara Falls, N. Y., Booth P521
 Aluminum Co. of America, Pittsburgh, Booth C122
 Aluminum Industries, Inc., Cincinnati, Booth A334
 Alvey-Ferguson Co., Cincinnati, Booth G608
 American Brake Shoe Co., Elyria, O., Booth B122
 American Brass Co., Waterbury, Conn., Booth D320
 American Carbide & Carbon Corp., New York City, Booth G621
 American Chain & Cable Co., Inc., Bridgeport, Conn., Booths D311 & D314
 American Chain Ladder Co., New York City, Booth C736
 American Cyanamid & Chemical Corp., New York City, Booth P523
 American Cystoscope Makers, Inc., New York City, Booth H610
 American Foundrymen's Asso., Chicago, Booth D141
 American Gas Association, New York City, Booth F617
 American Gas Furnace Co., Elizabeth, N. J., Booth C110
 American Machine & Metals, Inc., East Moline, Ill., Booth E604
 American Machinist, New York City, Booth H604
 American Measuring Instruments Corp., New York City, Booth F130
 American Photocopy Equipment Co., Chicago, Booth A321
 Ampco Metal, Inc., Milwaukee, Wis., Booth D611
 Anderson-Bolds, Cleveland, Booth B335
 Anderson Bros. Mfg. Co., Rockford, Ill., Booth D310
 Annis Co. (R. B.), Indianapolis, Booth I627
 Ansco Div., General Aniline & Film Corp., Binghamton, N. Y., Booth E137
 Aro Equipment Corp., Bryan, O., Booth C633
 ⚙️-Technical Book Dept., Cleveland, Booth C114
 Atkins & Co. (E. C.), Indianapolis, Booth A760
 Atlas Metal Stamping Co., Philadelphia, Booth B741
 Austenal Laboratories, Inc., New York City, Booth G604
 Automatic Temperature Control Co., Inc., Philadelphia, Booth B310
 Automatic Transportation Co., Chicago, Booth A405
 Automotive & Aviation Industries, Philadelphia, Booth A131
 Avery Engineering Co., Cleveland, Booth C630
 Aviation Maintenance, New York City, Booth D601
 Baker-Raulang Co., Cleveland, Booth D604
 Barco Machine Products Co., Cleveland, Booth C709
 Barrett-Cravens Co., Chicago, Booth C624
 Bath Co. (Cyril), Cleveland, Booth B736
 Bausch & Lomb Optical Co., Rochester, N. Y., Booth B141
 Bell & Gossett Co., Morton Grove, Ill., Booth G617
 Bellis Heat Treating Co., Branford, Conn., Booth A306
 Bergen Precision Castings, Inc., Pleasantville, N. Y., Booth B118
 Beryllium Corp. of Pa., Reading, Pa., Booth B709
 Better Finishes and Coatings, Inc., Newark, N. J., Booth F120
 Black Drill Co., Cleveland, Booth E114
 Blackstone Mfg. Co., Chicago, Booth J603
 Bonneville Power Administration, Portland, Oregon, Booth F604
 Braeburn Alloy Steel Corp., Braeburn, Pa., Booth D728
 Bramson Publishing Co., Detroit, Booth B725
 Bremerton Chamber of Commerce, Bremerton, Wash., Booth F604
 Brickseal Refractory Co., Hoboken, N. J., Booth D750
 Bridgeport Brass Co., Bridgeport, Conn., Booth A315
 Briggs Mfg. Co., Cleveland, Booth I621
 Brown Corp. (W. R.), Chicago, Booth C736
 Bruning Co., Inc. (Charles), Chicago, Booth C741
 Brush Beryllium Co., Cleveland, Booth H614
 Brush Development Co., Cleveland, Booth E617
 Bryant Heater Co., Cleveland, Booth F610
 Budd Induction Heating, Inc., Detroit, Booth A601
 Budd Wheel Co., Detroit, Booth A601
 Buehler, Ltd., Chicago, Booth B135
 By-Products Steel Corp., Coatesville, Pa., Booth B110
 Cadillac Gage Co., Detroit, Booth P527
 Cambridge Wire Cloth Co., Cambridge, Md., Booth A745
 Campbell Division (Andrew C.), Bridgeport, Conn., Booth D311
 Canadian Radium & Uranium Corp., New York City, Booth J611
 Carboloy Co., Inc., Detroit, Booth C340
 Carborundum Co., Niagara Falls, N. Y., Booth E628

Carpenter Steel Co., Reading, Pa., Booth D102
 Central Corp., Chicago, Booth D743
 Central Scientific Co., Chicago, Booth A744
 Chace Co. (W. M.), Detroit, Booth A310
 Chayes Dental Instrument Co., New York City, Booth K601
 Chemical Rubber Co., Cleveland, Booth C330
 Chicago Flexible Shaft Co., Chicago, Booth A341
 Chilton Publications, Philadelphia, Booth C150
 Cities Service Oil Co., New York City, Booth D709
 Cleveland Crane & Engineering Co., Wickliffe, O., Booth J604
 Cleveland Metal Processing Co., Cleveland, Booth I610
 Cleveland Pneumatic Tool Co., Cleveland, Booth D605
 Cleveland Tapping Machine Co., Cleveland, Booth C315
 Clinton Machine Co., Clinton, Mich., Booth A143
 Commerce Pattern Foundry & Machine Co., Detroit, Booth P519
 Compar-Instrument Co., Detroit, Booth A704
 Conover-Mast Corp., New York City, Booth D601
 Control Equipment Co., Pittsburgh, Booth I634
 Cramer Co., Inc. (R. W.), Centerbrook, Conn., Booth B335
 Cut-Off Clinic, Passaic, N. J., Booth A605

 Deepfreeze Div., Motor Products Corp., N. Chicago, Ill., Booth D714
 Delta Mfg. Co., Milwaukee, Wis., Booth A605
 Denison Engineering Co., Columbus, Ohio, Booth P500
 Despatch Oven Co., Minneapolis, Booth A320
 Detrex Corp., Detroit, Booth D325
 Detroit Stamping Co., Detroit, Booth D724
 Detroit Surfacing Machine Co., Detroit, Booth A627
 DeWalt Products Corp., Lancaster, Pa., Booth D336
 Die Casting, Cleveland, Booth P510
 Dietert Co. (Harry W.), Detroit, Booth B414
 Dilley Mfg. Co., Cleveland, Booth I622
 Dillon & Co., Inc. (W. C.), Chicago, Booth I611
 Divine Brothers Co., Utica, N. Y., Booth C734
 DoAll Cleveland Co., Cleveland, Booth B340
 DoAll Co., Minneapolis, Booth B340
 Dow Chemical Co., Midland, Mich., Booth B321
 Driver-Harris Co., Harrison, N. J., Booth A720
 Drop Forging Asso., Cleveland, Booth E109
 DuMont Laboratories, Inc. (Allen B.), Passaic, N. J., Booth A735
 DuPont de Nemours & Co. (E. I.), Wilmington, Del., Booth C130
 Duraloy Co. (The), Scottdale, Pa., Booth P513

 Eastern Stainless Steel Corp., Baltimore, Md., Booth D130
 Eastman Kodak Co., Rochester, N. Y., Booth B409
 East Ohio Gas Co., Cleveland, Booth F617
 East Shore Machine Products Co., Cleveland, Booth A111
 Elastic Stop Nut Corp. of America, Union, N. J., Booth A640
 Electro-Alloys Div., American Brake Shoe Co., Elyria, Ohio, Booth B122
 Electro Metallurgical Co., New York City, Booth G621
 Electro Refractories & Alloys Corp., Buffalo, N. Y., Booth P523

Elgin National Watch Co., Sapphire Products Div., Aurora, Ill., D331
 El Taller Mecanico Moderno, Cincinnati, Booth I632
 Elwell-Parker Electric Co., Cleveland, Booth B403
 Eutectic Welding Alloys Co., New York City, Booth C310
 Executone, Inc., Cleveland, Booth A630

 Fansteel Metallurgical Corp., N. Chicago, Ill., Booth P501
 Farmers Engineering & Mfg. Co., Pittsburgh, Booth I634
 Fawick Airflex Co., Inc., Cleveland, Booth A726
 Faxfilm Co., Cleveland, Booth B723
 Federal Electric Co., Inc., Chicago, Booth H621
 Federal Products Corp., Providence, R. I., Booth P520
 Federal Telephone & Radio Corp., New York City, Booth B740
 Fiberglas Corp., Toledo, Ohio, Booth A730
 Finnell System, Inc., Elkhart, Ind., Booth A711
 Firth-Sterling Steel Co., McKeesport, Pa., Booth B146
 Fitzsimons Co., Indianapolis, Ind., Booth P526
 Flow, Cleveland, Booth P510
 Forest City Foundries Co., Cleveland, Booth G613
 Fostoria Pressed Steel Corp., Fostoria, Ohio, Booth C751
 Foundry, Cleveland, Booth P504
 Frontier Bronze Corp., Niagara Falls, N. Y., Booth E110
 Fulton Foundry & Machine Co., Inc., Cleveland, Booth D624

 Gamma Instrument Co., Inc., New York City, Booth H623
 Gardner Publications, Inc., Cincinnati, Booth I632
 Gas Appliance Service, Inc., Chicago, Booth A337
 Gas Machinery Co., Cleveland, Booth F613
 General Alloys Co., Boston, Booth C146
 General Aniline & Film Corp., Binghamton, N. Y., Booth E137
 General Tool & Die Co., Inc., East Orange, N. J., Booth C706
 Globe Products Mfg. Co., Los Angeles, Booth A121
 Globe Stamping Div., Hupp Motor Car Corp., Cleveland, Booth I623
 Goodrich Co. (B. F.), Akron, Ohio, Booth I620
 Gray-Mills Co., Evanston, Ill., Booth C601
 Great Lakes Steel Corp., Detroit, Booth C730
 Gulf Oil Corp., Pittsburgh, Booth A410

 H & H Research Co., Detroit, Booth P522
 Hager (E. F. & Son), Queens Village, N. Y., Booth A748
 Harmon & Co., Chicago, Booth F611
 Harper Co. (H. M.), Chicago, Booth A727
 Harris Foundry & Machine Co., Cordele, Ga., Booth C702
 Hart & Co. (Frederick), Poughkeepsie, N. Y., Booth F140
 Haynes Stellite Co., New York City, Booth G621
 Heil Engineering Co., Cleveland, Booth A624
 Hercules Electric & Mfg. Co., Inc., Brooklyn, N. Y., Booth A620
 Herman Stone Co., Dayton, Ohio, Booth C750

Hevi Duty Electric Co., Milwaukee, Wis., Booth C141
Hines Co., Detroit, Booth A704
Hitchcock Publishing Co., Chicago, Booth J601
Holden Co. (A. F.), New Haven, Conn., Booth B147
Honan Crane Corp., Lebanon, Ind., Booth D741
Hoskins Mfg. Co., Detroit, Booth A722
Houghton & Co. (E. F.), Philadelphia, Booth D337
HPL Mfg. Co., Cleveland, Booth K635
Hupp Motor Car Corp., Cleveland, Booth I623
Hydraulic Machinery, Inc., Dearborn, Mich., Booth B720

Ideal Commutator Dresser Co., Sycamore, Ill., Booth C715
Illinois Testing Laboratories, Inc., Chicago, Booth D138
Illinois Tool Works, Chicago, Booth B324
Independent Pneumatic Tool Co., Chicago, Booth G603
Induction Heating Corp., New York City, Booth D340
Industrial Bulletin, Chicago, Booth D700
Industrial Gas Center, New York City, Booth F617
Industrial Heating, Pittsburgh, Booth D745
Industrial Press, New York City, Booth E133
Industrial Publishing Co., Cleveland, Booth P510
Industrial Steels, Inc., Cambridge, Mass., Booth D130
Industrial Tape Corp., New Brunswick, N. J., Booth B746
Industry & Welding, Cleveland, Booth P510
Infra-Red Engineers & Designers, Cleveland, Booth A123
Instrument Specialties Co., Inc., Little Falls, N. Y., Booth D335
Intercontinental Engineers, Inc., Chicago, Booth C332
International Nickel Co., New York City, Booth B102
Iron Age (The), New York City, Booth C150

Jack & Heintz, Inc., Cleveland, Booth B320
Janney Cylinder Co., Philadelphia, Booth H605
Jessop Steel Co., Washington, Pa., Booth A739
Jones Co. (C. Walker), Philadelphia, Booth I624

Kelley Co. (J. W.), Cleveland, Booth C137
Kennametal, Inc., Latrobe, Pa., Booth B130
Kerr Dental Mfg. Co., Detroit, Booth I629
Kett Tool Co., Cincinnati, Booth D737
King (Andrew), Narberth, Pa., Booth D118
Kolene Corp., Detroit, Booth E635
Krouse Testing Machine Co., Columbus, Booth A734
Kux Machine Co., Chicago, Booth A311

Lake Chemical Co., Chicago, Booth C749
Lakeside Steel Improvement Co., Cleveland, Booth E122
Lakewood Tool & Supply Co., Cleveland (Lakewood), Booth A336
Lansing Engineering Co., Lansing, Mich., Booth A750
Lectroetch Co., E. Cleveland, Booth L102
Lempco Products, Inc., Bedford, Ohio, Booth C620
Lepel High Frequency Laboratories, Inc., New York City, Booth K615

Lester Engineering Co., Cleveland, Booth A330
Lester-Phoenix, Inc., Cleveland, Booth A330
Lewis-Shepard Products, Inc., Watertown, Mass., Booth D617
Lieser (George H.), Berea, Ohio, Booth A704
Light Metal Age, Chicago, Booth D712
Lincoln Engineering Co., St. Louis, Mo., Booth A740
Lindberg Engineering Co., Chicago, Booth D146
Linde Air Products Co., New York City, Booth G621
Lion Mechanical Works, Long Island City, N. Y., Booth I625
Lithalloys Corp., New York City, Booth A714
Lithium Co., Newark, N. J., Booth E117
Lord Mfg. Co., Erie, Pa., Booth C760
Lukens Steel Co., Coatesville, Pa., Booth B110
Lukenweld, Inc., Coatesville, Pa., Booth B110

M. & C. Maintenance Co., St. Paul, Booth C756
Machine Design, Cleveland, Booth P504
Machinery, New York City, Booth E133
Machine Specialties, Chicago, Booth A325
Machine Tool Blue Book, Chicago, Booth J601
Magnaflux Corp., Chicago, Booth D113
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Steel Fabrication

General Review of German Metallurgical Practices*

By John H. Frye


Colonel, U. S. Army, Ordnance Dept.

(Now General Manager of Sales, Columbia Steel & Shafting Co., Pittsburgh)

DURING THE WAR the Ordnance Technical Intelligence Branch studied captured German matériel at Aberdeen and in various cooperating institutions.† In line with this program, teams of civilian technical consultants and army officers with specialized training followed closely our invading armies. Their object was, of course, to determine the type of weapons Germany had on the drafting boards or in the experimental stage, and to determine the trend of thinking of German scientists.

Having had a part in organizing these teams from the home base, it was my privilege to participate in the field work at a later date and — what is more important — to review their reports and findings. My own findings, confirmed by the U. S. Ordnance Department technical consultants, in regard to German applied engineering, the research panorama, and mechanical practices were thoroughly disillusioning! Instead of a pre-conceived notion of German efficiency and research, a paradoxical condition of efficiency and blundering was found.

Even before the war, Germany had cheap labor and so it was rather expected to find excessive labor expended in numerous handling and processing steps. At R. Stock & Co. plant at Stolberg in the Harz Mountains, for example, five turret lathe operations were done on five different lathes, whereas all could have been done on one machine with one chucking and one handling. With few exceptions most industrial plants of Germany wasted tremendous quantities of both manpower and machine tool time, yet during the war Germany was critically short of machine tools and toward the end acutely short of manpower.

*An address delivered before the Detroit Chapter,  November 19, 1945.

†A resumé of the metallurgical studies was presented in *Metal Progress* in February 1945.

Politics Interfered With Production

The saga of German science has been well advertised, yet world-renowned German metallurgists and research workers were thoroughly disgruntled with the lack of responsibility given them. The *Reichsforschungsrat*, the German equivalent to the National Research Council, was formed in 1940 by Goering but was not permitted to function until the last year of the war; consequently many scientists were resentful of the ineffective organization and it was intimated that more emphasis was placed on politics than on scientific ability. One instance was found at the Kaiser-Wilhelm Institute for Iron and Steel at Clausthal-Zellerfeld, where Doctors Pomp, Oelsen and Bardenheuer had conducted considerable research work and reported on a large number of projects. These projects were assigned to them by industry without being channeled through a central clearing house to avoid duplication of effort or to determine the need for the work from a national over-all point of view. The funds for the Institute were provided by the industry for which it was doing the work. Not until the last year of the war were 250,000 marks allocated by the government, for which no definite assignment was ever made.

However, the Council did accomplish the release of technical men from the army and secured high priority ratings.

Speer, Reichsminister of Armament and War Production, stated that although preparations for war had begun early and were methodically conducted, the extent of Germany's economic mobilization up to early 1942 was less than that achieved in World War I under more slipshod conditions. The responsibility for this condition was placed upon *Wehrmacht* (army) officers who prepared the pre-war plans. No attempt was made to consult or secure the cooperation of industrialists

until almost the beginning of the war, and then only second raters were engaged in the work. An inference is that a lack of vision of the officers discouraged the top-flight men in industry.

More important, only a short war was anticipated and mobilization plans and production schedules were based on this assumption. Even these short term plans were not fully realized because of government interference, lack of industrial experience on the part of the administrators, and lack of coordinated economic leadership.

In taking over the ministry, after the airplane accident that eliminated Todt, his predecessor, Speer's first move was to bring industry into the picture by creating *Hauptausschussen* or main committees, and later, the *Hauptringe* or sub-committees containing no military personnel. The military requirements were given to Hitler who made the necessary decisions, passed them on to Speer or Saur, and thus to the Commission. The plan as conceived should have functioned admirably but it was confused by the several political influences and personalities existing in the German government, including the activities and ambitions of the SS secret police.

"Pipe Line" Held One Year's Production

The Germans also had trouble with allocations and priorities. They had an organization (*Sonderausschuss*) similar to our War Production Board,

which consisted of some 200 committees, each concerned with a particular phase of war production. Both Speer and Saur state that the four-year plan should have been sufficient and effective but that it was carried out inefficiently and in an irresponsible manner. It is interesting to note that about 1944 there were approximately 15,000,000 tons of steel — almost one year's production at that time — in circulation, reserved, or in transit because of the ineffective priority system. The gradual acceleration of the mobilization tempo was deplored; public and private building continued, and civilian standards were maintained at too high a level in the pre-war years as well as the early war years. Top-flight government officials bickered about the dispersion of essential industry, machine tool expansion, priorities of materials, and labor for their respective agencies or industries. There was no actual head to coordinate the over-all war economy. Hitler acted as such but lacked the courage or desire to over-rule the wishes of favorites with the result that decisions were continually reversed; a state of confusion existed in industry.

Throughout the war there was a great deal of talk in this country to the effect that a democracy could not effectively compete with a dictatorship in the conduct of war. There was a great deal of logic advanced in this reasoning, but after reviewing the trials and tribulations of the German government during the war years there can be no other answer except a renewed faith in democracy!



Fig. 1 — Unloading Docks at August-Thyssen Works at Hamborn (Duisburg). Raw materials were delivered to nearly all steel plants in Germany by boat and barge on rivers and canals

The SS organization actively interfered and, in some instances, persuaded Hitler to reverse a previous sound decision, and this seriously interfered with the production of war materiel. For example, the SS operated some confiscated Jewish-owned factories and were ambitious to control additional plants. They were mainly interested in profit. Eventually their activities were confined mostly to soft drinks, cameras and similar luxury items, which were sold on the black market. In a very few instances an SS factory produced rifles and aircraft fuselage components. The SS wanted to start factories in concentration camps but Hitler was finally persuaded to rule against this idea because of their inefficiency and resultant wastage of machine tools and other equipment.

It was customary for Hitler to establish the production goal of war matériel for the next period of time. Because of interferences and inefficiencies this goal was seldom reached but apparently no official had the fortitude to admit this fact to Hitler. In fact it was customary to submit padded production figures.

Designs for Very Heavy Tanks

In 1941 Hitler discovered that German tank development was proceeding along bureaucratic lines, so the *Panzer* Commission under Prof. Prosche was formed. Prosche apparently had ability although was rather impractical; however, he was an intimate friend of Hitler. The *Panzer* Commission did not prove effective until the latter part of 1943 when von Heydekampf succeeded Prosche. Von Heydekampf was one of the best production men in Germany and it was under his leadership that the principal developments were made. Originally, the Commission was intended to design the tanks but Heydekampf soon had outside agencies for this with the Commission acting as a coordinating and approving agency. Thus tank designs were standardized and mass production was made possible.

However, Prosche remained an influential factor. The "Maus" tank was a Prosche design which weighed somewhat over 180 tons. There were a few other free thinkers in German tank design. For instance, a 1000-ton tank was developed by Krupp. However, after final engineering was performed the actual weight of the proposed tank would have been about 1800 tons and the idea was given up. Consideration was also given to a land cruiser weighing between 1000 and 1500 tons. This would have had three or four revolving turrets, each containing a 128-mm. gun and would have been 65 to 70 ft. long. We were told that Heydekampf and other tank experts in Germany

are of the opinion that exceptionally heavy tanks have little military value and complicate the transportation and movement necessary in warfare. In fact, it was reported that many German tank experts were concerned over the size and weight of the Tiger tank and were advocating much less weight for the same firepower.

Use of Low Grade Iron Ores

The Germans really made a silk purse from a sow's ear by producing quality steel from inferior materials. Swedish ores had always been used for blending in German blast furnaces and before and during the early part of the war large stockpiles were accumulated. As transportation became curtailed and stockpiles depleted, it was essential that means be developed to get along with low grade domestic ores. Considerable work was done on this problem and the solution was one of the marvels of the entire German war effort. These ores were widely variant in iron content (some as low as 19%) and in lime, silica, phosphorus and sulphur. Several methods were employed for concentration and beneficiation. There are vast known deposits—billions of tons—of these ores and their successful use would give Germany independence from foreign ores.

Improvements in Bessemer Practice

Thomas steel (basic bessemer) comprised about 45% of total production. Shell forgings, castings and numerous miscellaneous items were made from it exclusively. It was also upgraded to produce plates and cold rolled sheet steel. The deleterious effects of nitrogen were recognized and much research work was done to make Thomas steel competitive in quality with openhearth steel. At one time, every major mill and research agency was involved in this research, and it was determined that the amount of dissolved nitrogen was a function of temperature and time of blowing. As a remedy, the air blast was enriched with oxygen, and limestone, mill scale or iron ore was added to the charge. The flow of metal in the vessel was studied in an effort to reduce the time required for blowing as well as the time of contact of the blast with the metal. But temperature was found to be most important, so they added cold steel scrap after three-quarters of the blow was completed. Ferro-alloys were added after the blow. In addition to improving the quality of Thomas steel—and a goodly tonnage of this low nitrogen type was produced—the resulting slag was nitrogen-rich and, Germany being short of agricultural fertilizers, this slag found a ready market.

During the war we were surprised when metallurgical examinations of German matériel did not show more extensive use of boron treated steels, especially in view of the shortage of alloying metals. Bardenheuer and Pomp, of Kaiser-Wilhelm Institute, reported that boron is not eliminated on remelting scrap in the Thomas converter and this would create quite a problem with residuals.

Through our technical publications the Germans were familiar with the important work done in this country on hardenability tests and hardenability bands. In spite of this, the only use made of the Jominy test was curiosity tests in research laboratories. Steel consumers used the old cut-and-try method of sectioning slugs after heat treatment. Steelmakers depended upon "experience"!

Duplex Steel

Another 45% of German steel production was openhearth quality and the electric furnace produced 10% more. During the war there was always a critical shortage of both types but the Germans used a great deal of ingenuity in alleviating this condition. Duplexing and triplexing were common. Duplexing was usually extremely fast; only about two hours were required to refine Thomas steel in the electric furnace.

To increase the production of steel for quality products, such as gun tubes, a practice of mixing Thomas, openhearth and electric furnace steels was developed at the Hermann Goering Works at Braunschweig and later was used by several other mills. This consisted of mixing two or more of these grades in proportions established by the quality required by the end product. In addition to increasing the tonnage of quality steel, this made the most effective use of alloy steel scrap. It was required that all alloy scrap be segregated by grades, accomplished largely by spark testing, and this created an excessive drain on time and labor at the mills.

Ingots were usually bottom poured and hot topped. One universal condition that existed throughout the industry was the very poor surface condition of the ingots. For all high quality products it was necessary to turn or plane the entire surface. Ingots made at the Hermann Goering plant at Braunschweig are an exception to that statement. Hubert Smith, Ordnance Technical Investigator, states that no other mill was "ingot surface minded" and that the superior condition here was undoubtedly due to a man named Hoffman, who had spent several years at the Carnegie-Illinois plant in Gary. A heavy rosin-like coke oven by-product known as *Cumaron Harz* was sprayed on the mold walls.

Hermann Goering Steel Plant

J. D. Dickerson, Ordnance Technical Investigator, in his splendid report on the Hermann Goering plant says that it is the finest and most efficient steel plant in Germany. In Hubert Smith's opinion the whole plant is a classical experiment. Located close to a gigantic deposit of low grade Salzgitter and Peine ores, it has developed a process for using them exclusively for the production of quality steel. This serves to emphasize the tremendous potential of German steel production.

This plant represents an investment of one billion *reichsmark*—about \$400,000,000 at pre-war exchange rates—and is thoroughly modern. The management is of the opinion that it can continue to use those low grade ores and compete with other German mills using Rheinisch ores with or without a mixture of Swedish. The mines are equipped to produce 40,000 tons per day; the ten blast furnaces erected—out of the 32 originally planned—are capable of 5000 tons of iron a day, and the steel plant has an annual capacity of approximately 1,250,000 tons of ingots.

This plant was constructed because of the serious steel shortage in 1936 and 1937. Many of the smaller plants were forced to shut down at that time due to a lack of ore from export limitations imposed by Sweden combined with stockpiling by the German government. Steel produced by the large "combines" was diverted to their wholly owned or partially owned fabricating companies. Consequently many of the smaller organizations were forced to join the larger ones in order to exist. The steel shortage became so acute that the remaining smaller companies banded together and demanded that the domestic low grade ores be utilized. In addition to expanding pig iron production it was also demanded that new steelmaking facilities be created in Western Germany, independent of the organized Western Germany Iron and Steel Industry. There was considerable opposition to this plan but the government finally agreed, provided the new plant was located in Central Germany. The project was a government owned corporation, with only a few shares of preferred stock privately held.

All in all, the German iron and steel industry did a remarkable job of making quality steels from inferior materials. In no way were their steels superior to those of this country—in many instances, they were below our standards—but through research and ingenuity an adequate quality was maintained. Had a like amount of attention been given to production details—such as ingot mold preparation, handling, or cross-hauling—they would have *made* much more steel.

Inadequate Transportation

This cross-hauling of parts and semi-finished material was a serious deterrent to German production. Friedrich Krupp of Essen stated that German industry was more hampered by the lack of adequate transportation facilities than any factor, other than labor. In late 1942, plants were dispersed, which increased the cross-hauling and, when added to the military traffic, over-taxed the inadequate transportation systems. Transportation facilities were not increased at the start of the war commensurate with the new manufacturing facilities.

Most of the German steel mills were located on rivers or canals and in all but one instance it was observed that their raw materials were delivered by water. All mills had some stock of materials on hand and all that we observed, except Krupp's in Essen, were in a position to produce some steel in spite of severe bomb damage. A number had closed as much as six months before the end of the war, not because of plant damage or lack of raw materials, but because bombing had so badly disorganized the railroads that it was impossible to ship their finished products.

Damage by Bombing

It was surprising to see how badly a plant could apparently be damaged and still function to some degree. We saw one wire and nail plant at Hamm which had 75% of its buildings destroyed, yet they had pulled the debris from the immediate vicinity of some equipment, cleaned and oiled the

moving parts and were producing 30 tons of nails, wire and wire rope per day. This quantity could have been increased to 100 tons a day if transportation facilities were provided, and to 200 tons in 60 days' time. Few blast furnaces were so damaged that they could not be repaired within a few days. One of the marvels of construction was the industrial smoke stacks. In many instances the stack was the only standing part of a plant. Sometimes there were artillery shell holes through them and occasionally one would be seen that could compete with the Leaning Tower of Pisa, but not once did we see a stack down.

Alloy Shortages

When the national emergency alloy steels (NE steels) were first introduced in the United States they met considerable resistance by the users. We had two alternatives: One, that of drastically reducing alloy steel consumption, was impossible; the other involved strict segregation and utilization of alloy scrap by grades. After seeing the confusion and interference with production that the latter method of conservation caused in Germany there can be no question about our following the wiser course.

Herr Speer stated that economic warfare was neglected because the German General Staff and Government had no economists on the staff! The invasion of the Balkans is said to have been planned without reference or thought to the tremendous natural resources, such as ores for ferro-alloys, existing there. However, this does not fit with German actions nor with other statements of

Fig. 2 — Typical View Within the August-Thyssen Works at Duisburg on the West Border

of the Ruhr, Cleaned Up After Some Concentrated Attention From British and American Flyers



Speer and Saur. Others say that economic phases were very influential in forming defensive strategy. For instance, Hitler personally insisted on defending economic resources, such as Nikopol, but the General Staff wanted to abandon it, arguing that 2½ years' supply of manganese was available, and the Roumanian and Yugoslav production would help keep the German steel industry running.

However, ferro-alloys were extremely critical in Germany long before the war ended. No copper could be used in steel, while nickel and molybdenum, which had to come largely from stock-piles, were used only for special steel applications. The Russian Nikopol mines supplied ample manganese ore which, with the chromite from Yugoslavia and Turkey, enabled the Germans to produce chromium-manganese and chromium-silicon steel. As these ore sources were lost through retreats, and the stock-piles dwindled, the permissible analyses of alloy steels became leaner and leaner. A commission was eventually established to govern the consumption of alloying elements; it exercised absolute control through the supervision of specifications. Chromium became so scarce and was so carefully controlled that its use required full recovery from steel scrap. Manganese conservation varied with availability, but there were drastic reductions in the amount carried in the steel, even in shell steel, during the last war year.

Vanadium From 0.1% Ore

During the later years vanadium was about the only alloying element available to the Germans and its recovery from the low grade iron ores was imperative. Dickerson states that the Salzgitter ores contain about 0.1% vanadium and are the richest of the German iron ores in this respect. The blast furnace iron made from this ore contains approximately 0.3% vanadium and after blowing the Thomas slag averaged about 1.5% vanadium. At the Hermann Goering plant the dust and spittings from the converters and the vanadium-rich slag were charged into a blast furnace reserved for this purpose and re-smelted, yielding iron containing approximately 1.5% vanadium, 9.0% phosphorus, and 1.5% carbon. This iron was then blown and the resulting slag averaged about 14.5% vanadium. It was sent to a chemical plant for recovery as vanadic acid and this purified material was

subsequently converted to ferro-vanadium.

At Burbach Eisenhütte at Saarbrücken a converter was set aside for partially blowing the pig before the metal was put into the mixer. The slag from this preliminary blowing contained from 1.0 to 1.5% vanadium. Again, one blast furnace was reserved for the production of vanadium iron; the charge consisted entirely of vanadium slags and spittings with no addition of iron ore. The resulting iron had a vanadium content of approximately 0.5%, which was again blown in the special converter and the slag formed contained from 6 to 8% vanadium; this was rich enough to be recovered chemically. Vanadium production at this



Fig. 3 — Interior of Projectile Shop at Krupp's in Essen. The roof seems to be open but there has been minor damage to cranes and cranesways. The men are discussing a shell for the 80-cm. (31½-in.) siege gun used effectively at Sevastopol. Two ballistic windshields for this shell are in the left foreground

plant amounted to approximately 15 tons of contained vanadium, and at Hermann Goering works from 50 to 100 tons were recovered per month.

Cast Iron Projectiles

The German army estimated a requirement of 4,000,000 mortar and grenade shells per month and, in view of the limited forging and pressing capacity, it was apparent that any such quantity must be made from castings. The original physical requirements of mortar and grenade shells were for a tensile strength ranging from approximately

85,000 to 110,000 psi. and, when detonated, to produce a minimum of 400 pieces of 4 g. or more weight. These requirements were considerably reduced later because of labor shortages and the enforced manufacture of these shells from gray iron and semi-malleable iron.

German foundry metallurgists seemed to have the opinion that they originated cast shells of suitable quality, but practically since the beginning of the war the U. S. Ordnance Department has approved and procured cast steel 60 and 81-mm. mortar shells. During the last two years of the war, Germany was forced to use cast shells for rifled guns in addition to those for smooth bore mortars. This was a matter of necessity, with full realization that greater allowances in eccentricity must be permitted as well as facing the possibility of imperfections such as blow-holes. One firing of a semi-pearlitic malleable iron 88-mm. anti-aircraft shell was reported to have a deflection variation of 800 m. at 11,000-m. range, which was attributed to the eccentricity of the shell walls. As a precaution against damaging defects, a hydrostatic test was added to the usual chemical and physical tests. For the 120-mm. mortar shell a pressure of 400 atmospheres was required.

German foundrymen claimed that sand mold castings did not stand the hydrostatic tests because of porosity and seepage, and therefore it was necessary to use permanent molds of cast iron. At the Friedrich Wilhelm Hutte in Mulheim-Ruhr, cast iron molds for six shells each were used for producing the 105 and 120-mm. shells, and molds for four shells each were used for the 150-mm. shells. These molds could be used for 3000 to 4000 casts, but the surface finish of the product was extremely poor. To reduce defects and improve the ballistic properties, an allowance of 3.5 mm. (more than $\frac{1}{8}$ in.) was made for machining. This seems to be an excessive wastage of metal, manpower and machine tool hours.

To ease the steel requirements, and to improve production of cast shells, the Germans often used malleable pearlitic iron castings. Originally white iron castings were made by the usual malleable processes and reheated to 1740° F., air cooled and tempered at 1000° F. Because of the long heat treating cycle and the limited furnace capacity, a pseudo-malleable iron was later produced by partially malleabilizing gray iron. A few foundries did produce what we would call a quick anneal malleable iron by heating the white iron from 1700 to 1750° F. for 10 hr., after which they were air cooled to 1300° F. and placed in a cooling chamber to retard pearlite transformation (which occurred in about one hour). The Germans also found that white iron transformed to pearlitic malleable

very rapidly in molten salt, and it was reported that a much finer and superior structure was obtained in this manner.

Cast Gun Tubes and Armor

Roy Gezelius, technical investigator for the Ordnance Department, states that German foundries almost universally lack mechanization, and the management of the plants which he inspected stated that the labor rates were so low, compared with the interest charges on capital expenditures required for machinery, that it would be unprofitable to install labor saving equipment.

The Germans have made some progress in the production of centrifugal castings, but their general practice is not equivalent to the standards and efficiency expected in the United States. However, their processing of cylindrical parts is equivalent to our practices and they have introduced some interesting innovations.

We found two or three modifications of this type of equipment, but essentially they consist of an alloy steel cylindrical mold that is rotated within a water jacket at a speed that depends upon the size and weight of the part. The most successful of these machines with horizontal axis is tilted at an angle of about 20° when the metal is poured in. Before this, the surface of the mold is covered with a $\frac{1}{2}$ -in. layer of fine warm sand, distributed uniformly by introducing it in the revolving mold by means of a pipe with slit top which dumps the sand upon turning. The sand must be properly distributed throughout this pipe to provide uniform distribution in the mold. The centrifugal force assists in further equalization and holds the dry sand against the mold wall. By the use of this sand "liner" it is possible to produce from 2000 to 3000 castings per mold.

Watertown Arsenal has been casting gun tubes in the centrifugal manner for a great many years, extending almost back to the end of the last war. The process of casting and auto-fretting used at Watertown was developed there, and was described by F. C. Langenberg in *Transactions* of this Society, Vol. 8, p. 447, and by Gen. T. C. Dickson in *Transactions*, Vol. 18 (1930), p. 212. Many of the operating details have been kept secret until the beginning of this war.* The process used by the Germans is comparable in many respects except that the introduction of the sand layer does provide longer mold life.

Investigator Gezelius also found that the production of cast armor in Germany never became

*See the brief description of operations at Dickson Gun Plant in Houston, Texas, in "Critical Points" for July 1945.

as significant as it did in the United States. He estimated their maximum production at 3000 tons per month. Most of the castings were comparatively small, though a few observation towers and gun turrets for the West Wall were produced. No homogenizing treatment was employed, as the Germans believed that grain growth during this treatment was injurious.

Armored castings were quenched in oil because the producers believed that water quenching would result in cracks. Gezelius states that this belief probably arose from the fact that none of the plants had made provisions for controlled time quenching, and depended entirely upon the worker's experience for control. The usual inspection was a visual examination, although a few foundries did use destructive testing on pilot castings. In his opinion but few of the German armored castings would pass the radiographic standards required by our Ordnance Department.

Precision and Die Casting

Precision or "lost wax" castings* of intricate shape, or of unmachinable alloys, played an important role in the production of war matériel in the United States, and it was surprising to find that German ingenuity had not made use of this process. However, they used the term "precision casting" instead of die casting, and this resulted in many a wild goose chase for those investigators interested in truly precision methods.

A. T. Liligren and J. J. Lowe, Ordnance Technical Investigators, made a thorough examination of the German die casting industry and techniques. They report that the quality of work, and most definitely the equipment, was far below that common in the United States. Workmanship was very good, compensating to some extent for the inadequacy of equipment and testing methods. Die life was shortened and the castings had wide size tolerance and poorer finish because of the inferior die steels, low in alloy, that the Germans perforce used. Only on two occasions did these investigators find X-ray inspection apparatus, and both of them were inadequate for the full range of sizes. Sometimes a casting from a new die was sectioned for examination, but inspection of the finished castings was essentially visual. Even weight testing was not employed.

Mahleky of Stuttgart was the only plant that produced die castings comparable in quality with ours. This plant was the most important in Germany, making 200 tons or 65% of all magnesium,

800 tons or 35% of all aluminum, and about 20 tons of zinc die castings per month. The magnesium alloy was generally 90% magnesium and 10% aluminum while the principal aluminum alloy was 79% aluminum, 10% manganese and 11% zinc. The zinc castings were a copy of one of New Jersey Zinc Co.'s standard "Zamak" alloys.

From Liligren and Lowe's report it is certain the Germans did not consider their die casting industry as important to war production as was the case in the United States, and again this is borne out by the examination of captured matériel.

Forging Practice

Forging capacity was one of the serious bottlenecks in German war production and, like many other processes, was a paradox with respect to modernization and efficiency. Between 1935 and 1939 a number of forge plants had installed some modern equipment but this was usually paced by slow moving accessory equipment which limited the production of forgings.

One German metallurgist, whose name I do not recall, reported that an attempt had been made to forge ingots from casting heat but — as may be expected — this proved unsuccessful. It seemed to be their general practice to equalize the temperature of large forging ingots in the neighborhood of 1100 to 1300° F. and then reheat to forging temperature. Smaller ingots and rolled billets, except those of higher alloy composition, were normally cooled in sand or ashes.

Although many gun tubes were centrifugally cast, most of them were press forged. Electric furnace steel was used insofar as available, after which both acid and basic openhearth steels were accepted. Tom Foulkes, Ordnance Technical Investigator, reports that ingots for very large forgings, such as the 80-cm. gun tube made at the Krupp plant in Essen, were poured from combined electric furnace, acid openhearth and basic openhearth steels because of limitations in furnace capacity. Silicon-killed manganese-vanadium steels for the small to medium sized forgings and chromium-vanadium steels for larger types were generally used. Gun tubes and other large components were press forged on hydraulic presses with capacities up to 15,000 tons.

Foulkes reported one or two instances where ingots intended for gun tube forgings were cast alternatively with breech end down, and others with muzzle end down, but considerable experience showed no recognizable advantages of one method over the other. It was pointed out that this may not apply to all calibers, since 88-mm. tubes were the only ones tried in this way. Gun

*See "Supercharger Buckets Mass Produced by Precision Casting" by Arthur E. Focke, *Metal Progress*, September 1945.

tubes were rough bored prior to quenching, and most manufacturers were equipped with modern vertical furnaces and quench tanks. Bochumer-Verein at Bochum had vertical furnaces and tanks that could handle gun tubes 90 ft. long. These furnaces had as many as 700 multiple burners to provide uniformity in heating. Skoda and several other plants were reported to obtain a better degree of uniformity by slowly revolving the tube in the vertical furnaces during the heating cycle.

Medium and small forgings were made on equipment of all standard types which varied from the entirely inadequate to the most modern. As a result there was a wide range in quality and accuracy but, from observation of their plants and particularly from examinations of finished forgings on captured matériel, it seems apparent that the accuracy to size and shape was far below our commercial standards.

In their industrial preparations for war the Germans installed a considerable amount of new forging capacity, especially that required for making gun tubes and shell forgings. The latter apparently received the greatest attention, and although there were several especially well equipped shell forging plants the supply was far from meeting the demands. However, it must be remembered that the number of rounds of artillery ammunition expended per man was far greater during this war than ever before. The "hot-pierce and push-bench" method was generally used except for small calibers, such as 37 and 40 mm., which were made by press operations. (Compare the U. S. practice of machining from bar stock.)

By Government order, Thomas or basic bessemer steel only was used for army high explosive shells. Shell forging plants having openhearth furnaces but no converters were required to purchase their billets. In the last six months of the war, when excessive cross-hauling and bomb dam-

age had snarled up the railroad facilities, this restriction had to be revoked. Typical analysis was 0.57 to 0.67 carbon, 0.50 manganese (average), 0.35 to 0.50 silicon, 0.06 to 0.09 phosphorus and 0.025 min. aluminum. The high phosphorus was believed to provide better shell fragments, and was added in the form of ferro-phosphorus or phosphoric spiegel. A hot deformation test, comparable with a hot Erichsen test, was performed on Thomas shell steel billets. A disk 10 to 15 mm. thick was cut from representative billets and was cupped after heating to 1300° F.; the deformation before fracture must be equivalent to the disk thickness.

Foulkes sums up his opinion of German forging practices as follows:

"1. German forging technique was comparable to that followed in the United States.

"2. No instance of recognized German superiority was encountered.

"3. The quality of forgings appeared to have been maintained during the war.

"4. Increase in facilities had been confined, almost entirely, to shell forging equipment.

"5. Accessory handling equipment was less modernized and less efficient than that in use in the United States except in new shell forging shops."

Powder Metallurgy

In the field of powder metallurgy the hard metals or carbides had been developed and fully utilized. German practices and quality of product were comparable to that of this country and forward looking research was being carried on, largely by Messrs. Walter, Kieffer and Gehm. Martin Fleischmann and Gregory Comstock, U. S. Tech-

Fig. 4 — A Dummy Plant to Represent the Skoda Works Was Built About Six Miles Distant From the Camouflaged Actuality. This shows the base of one of the chimneys; all construction was of reeds woven over rough lumber skeletons. All the views in this article are from photos by Charles C. Park, Jr., of the U. S. Geological Survey



nical Investigators, made a thorough investigation of their practices. A review of Comstock's data and reactions is given on page 117 of this issue.

Research and developments on mechanical parts made of metal powder were curtailed in 1935, and the thinking of most German engineers and designers is at the least no later than that. However, a limited group of production engineers have the vision to see the proper and competitive applications of powder metallurgy and it can be expected that rapid advances will be made in this direction in a few years of peace, given the opportunity.

The monthly consumption of iron powder in German territory was distributed as follows:

2500 tons for shell rotating bands

30 to 50 tons for oil-less bearings

10 to 15 tons for sintered iron and steel mechanical parts

These items were made from powder by the "Degussa" or disk process. Carbonyl iron was used for magnets.

Iron Rotating Bands for Projectiles

Dr. Kieffer had much to do with the development of shell rotating bands, made of sintered iron, and it was interesting to hear him state that they were used as a matter of expediency. Setting a numerical figure of 10 as the efficiency of copper-zinc bands, he said that the early sintered iron bands had an efficiency of 6 to 7, while bi-metal (copper-clad rolled iron) was 8 to 9. Later the tensile strength and elongation of the iron compacts was increased by using greater compacting pressures and the relative numerical rating increased to as much as 12. However, there were 18 different companies making sintered iron bands and the quality varied considerably, ranging from 50 to 150% of the efficiency of copper-zinc alloy bands. (Consideration must be given to the fact that these ratings were obtained, at least partially, from firing tests and that the quality of German gun tubes may have varied more than normal because of ferro-alloy shortages. Also, more than usual consideration should be given to the possibility that iron bands are better than copper-zinc alloy to resist the higher pressures in the gun tube developed by the higher muzzle velocities from the new types of ammunition.)

Sintered iron bands were used on 20-mm. to 210-mm. shells inclusive. Bands for the smaller calibers required a tensile strength of 10,000 to 13,000 psi. while the larger calibers required 18,000 to 22,000 psi. After sintering, the bands were immersed in hot paraffin for 20 min. to prevent intergranular corrosion and to reduce friction

when fired. Bands for calibers larger than 210 mm. were made from rolled soft iron due to the lack of presses large enough for compacting them.

Dr. Kieffer was emphatic in his statement that lack of vision and of engineering ability were solely responsible for the extremely limited use of sintered iron and steel compacts for mechanical parts. At the close of the war not more than a half-dozen types of parts were being so made. The industry was not permitted to do any development work, even to the extent of making up sample parts, unless prior approval of high governmental officials was obtained. It required two years' effort on his part to secure permission even to review the drawings for Junkers' engines. Twenty-five parts were selected and production was ordered, but the U. S. Army Air Corps bombed most of the required presses out of existence while in transit and the



Fig. 5 — Milk Cows Taking a Plow to the Fields — A Common Sight, Unusual Only in Showing a Man Going Out to Farm

war ended. At the time of our visit, attempts were being made to find the remainder of the equipment for "peaceful pursuits".

Sintered steel compacts containing 0.70 to 0.90 carbon were used for oil pump gears, the follower plate, and the follower floor plate for the Mauser rifle and machine pistol. The carbon was introduced by mixing gray iron powder with the pure iron powder. Sintered iron was used for oil-less bearings, rotating bands, magnets, 9-mm. bullets and furniture caster rollers. It was ridiculous, of course, to use compacting capacity for simple screw machine parts and malleable iron jobs, such as bullets and rollers, while critically short machine tools and labor were whittling out complicated parts easily made from powder. In keeping with this disordered thinking we found the management at Vereinigte Deutsche Metallwerke at Ettlingen experimenting with newspaper type

made from iron powder and mozaic tile from ceramic powder.

An interesting feature noted at Metallwerke Plansee at Reutte in the Tyrol was the use of multiple dies for compacting. Some of these dies had as many as 12 sections, each of which had an adjustable stroke, so that the compacting pressures could be varied on different sections of the same part. By this means it would apparently be possible to make complex parts, having a variable cross-sectional area with a uniform, or nearly uniform, density.

Another practice not common in the United States is that of double pressing and double sintering to achieve greater density. This is accomplished by compacting, sintering at 1800° F., re-pressing with initial pressure, and re-sintering at 2200 to 2350° F. This double treatment is reported to produce a density of 7.2 to 7.3 as compared with 6.8 to 6.9 for the usual single process, and about 7.9 for ingot iron.

Physical Tests for Iron Compacts

There were no tests of physical properties required by specifications for parts made from iron powder, although several German metallurgists had quite definite ideas about the characteristics required for satisfactory performance. Several manufacturers had established minimum physical standards and we were told they were the producers of the best rotating bands. Metallwerke Plansee were the most meticulous in this respect. Triplicate samples for testing were taken from the production line every 3 hr. The testing procedure was as follows:

1. Carbon analyses on sintered steel parts and infrequent oxygen determinations.
2. Micro-tensile tests made on specimen from the finished parts. For sintered steel, not quenched, the tensile strength ranged between 65,000 and 90,000 psi.
3. Charpy micro-impact tests were taken from the finished part. A minimum of 200 cm-kg. (14 ft-lb.) was reported to be necessary, and 300 cm-kg. (22 ft-lb.) considered optimum for most sintered steel parts.
4. Occasional microscopic examinations to ascertain if the proper type of pearlitic grain structure was being obtained.
5. Rockwell hardness tests, while not accurate due to intergranular crumbling, gave comparative data and some idea of uniformity as to density.

Rolled and Drawn Bars

The Klockner Works, Troisdorf, produced more than 12,000 different hot rolled and cold drawn special shapes. Some were quite intricate

and the staff was especially proud of the size tolerances and sharpness of edges they were able to hold on the hot rolled sections. This mill was one of the largest producers of cold finished bars in Germany.

Our metallurgical examination of captured German matériel during the war indicated that cold drawn bars and tubing and cold rolled strip were used only because of size accuracy, machinability and finish. This was confirmed by observation and questioning. They did not take advantage of the improved physical properties obtained by cold drawing or cold rolling. Only in steel cartridge cases did they intentionally utilize the characteristics obtained by cold work in fabrication. This is contradictory to our common use of cold worked steel products as engineering materials; small caliber high explosive shells, fuze components, primer tubes, rocket motor tubes and hundreds of other items were made of them where moderately high yield strength was required.

The metallurgical staff at Klockner Works was more familiar with the potential value of cold working than those that were interviewed from other mills and, oddly enough, their information came largely from U. S. technical publications. Their only reply to questions as to why cold worked or cold worked and strain relief annealed materials were not fully utilized in ordnance production was a shrug of the shoulders and "We received no encouragement".

It is impossible to tell in a short space of the many, many interesting metallurgical practices which were observed by our technical investigators, but the commercial technical data collected by them are being rapidly declassified and will be available to American citizens. The Ordnance Department was fortunate in securing the services of outstanding scientists and engineers to investigate the technical advances of Germany. Both Ordnance and Industry owe a great debt of gratitude to those men who gave their time and often suffered severe hardships to serve their country. A wealth of information of great value has been obtained and the field of metallurgy, both from a mill production and consumer's point of view, was thoroughly covered.

The one thing that has been proven to me again and again from these hundreds of reports and my own personal observations is that in war, as in peace, the combined effort of free men is the potential behind the greatest accomplishment this world has ever known.

A democratic government, and free, competitive enterprise, is more efficient and more productive than a dictatorship any day, any time, any where!

Estimation of Spatial Grain Size

By William A. Johnson

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GRAIN SIZE has important aspects in practical as well as theoretical metallurgy. Processing of brass is controlled largely by grain size which is considered more significant than hardness. It is known to be a major factor in the deep-drawing quality of steel and is a provision in commercial specifications for carburizing steels. Creep strength is also influenced markedly by grain size. Quantitative relations between properties and grain size may even exist, but their determination is contingent on development of more precise means for evaluating grain size than are now available.

Under these circumstances it is strange that grain size is almost universally estimated from observations on *plane* surfaces, whereas the actual properties of the metal are undoubtedly determined by the size of the grains *in space*. Observations on a plane, which cuts the several grains in a field at random positions from a corner to the largest cross-section, always yield a *range* of grain sizes, even in the rare case of constant spatial size. Under the most favorable circumstances not more than half the grains shown on a polished section of a commercial metal (called "planar grains" in this article, to distinguish them from the actual grain sizes of the "spatial grains") will lie in the range covered by a single grain size number as defined by the American Society for Testing Materials' specification. Even if the metal has a theoretically uniform spatial grain, a metallographic section will have at least one-quarter of its area covered with planar grains of smaller size (larger grain size numbers).

Undoubtedly this situation exists because it is relatively easy to estimate the planar grain size of substantially equi-axed crystals by comparing them with standard micrographs, and because of

the lack of information about how to translate these random sections into an accurate estimate of the distribution of spatial grain sizes that are responsible. Fortunately such an estimate is readily possible, and this article will indicate the method, leaving aside the involved mathematical analysis on which it is based. This analysis is based on the experimental observations reported by E. Scheil in *Zeitschrift für Metallkunde*, 1935 and 1936, and *Archiv für das Eisenhüttenwesen* for 1937.

Four steps are necessary: A. Estimate the relative area of each size of the grains showing on a micrograph. B. Calculate from this estimate the relative distribution of spatial grains. C. Estimate the average spatial grain size. D. Calculate the standard deviation, employed as a measure of the uniformity of grain size.



Fig. 1—Sample of Carburized Steel (Hyper-Eutectoid) With A.S.T.M. Grain Size No. 1. (100 diameters)

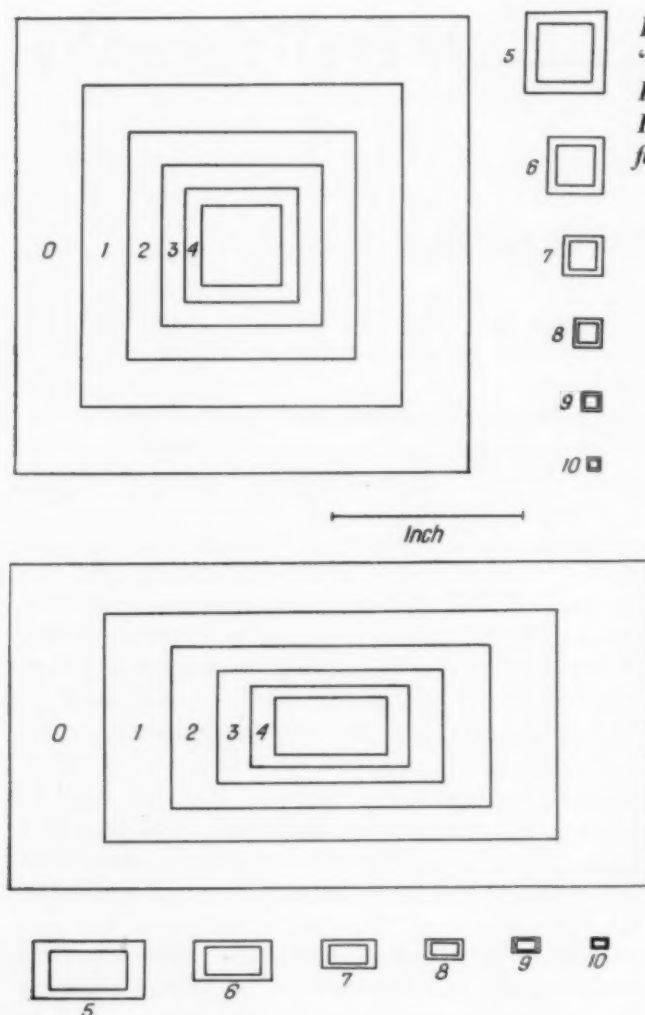


Fig. 2—Square and Rectangular Grain Size Grids With "W" Numbers, for Estimating Areas of Individual Planar Grains. Full size for micros at 100 diameters. For use, make positive photographic prints on heavy film—tracing linen is not sufficiently transparent

network of 1 sq.in. hexagons have little relationship to reality, and tend to deceive the observer and lead him to the erroneous belief that such a steel contains nothing much but grains of a single size.)

Again, from the above equation the mean planar grain area of A.S.T.M. grain size No. 2 would be $\frac{1}{2}$ sq.in., No. 3 would be $\frac{1}{4}$ sq.in., and so on, the mean planar grain area decreasing as the grain size number increases.

The A.S.T.M. definition could be modified to be suitable for the problem of spatial grains simply by restricting it to apply to a single grain. Such a definition would be (using the letter W as the grain size number of a specific grain):

Planar grain area at 100 diameters
magnification = 2^{1-W} sq.in.

It is convenient to make the further definition that the spatial grain whose greatest cross-sectional area is of size No. W is of spatial size No. W. Under this circumstance a specimen having a uniform spatial size of No. W will have a range of planar sizes from No. W up (and experience shows it will have an A.S.T.M. mean size of about No. $W + 1$).

To avoid confusion when spatial grain size data are compared with A.S.T.M. data, it is more convenient to have the spatial grain size system defined so that the mean grain size number is the same, or very nearly so, in both systems for most specimens. On this basis the planar grain size number, W, of each individual grain visible on a plane surface is defined by the following relation, obtained from the one immediately above by changing the exponent from $1-W$ to $2-W$:

Planar grain area at 100 diameters
magnification = 2^{2-W} sq.in.

According to this relation and definition, a single grain having an area of 2 sq.in. through its maximum cross-section, when measured at 100 diameters, is of W size No. 1; if it has an area of 1 sq.in. its size is No. 2; size No. 3 has an area of $\frac{1}{2}$ or 0.5 sq.in. and so on. In making actual estimates of spatial grain sizes from micro-sections it is not necessary to determine the exact size of every planar grain in the field of view, but it suffices to group them in ranges of 1 grain size unit. Thus, all grains of size No. $1\frac{1}{2}$ to $2\frac{1}{2}$ (1.41 to 0.71 sq.in. in area) are recorded as No. 2.

Such estimates are quickly made by comparison with a set of standard areas representing

To determine a distribution of spatial grain sizes, it is necessary to measure individual grains; therefore a new grain size standard must be defined, but it is desirable that any new definition be as similar as possible to the A.S.T.M. standard. A further fortuitous advantage of the established system is the logarithmic relationship between the dimensions of the grain and the grain size number, which greatly facilitates the numerical analysis of data. The A.S.T.M., or Timken, grain size numbers are defined by the following equation:

Number of planar grains at 100 diameters
magnification = 2^{N-1} per sq.in.

where N is the grain size number. This may also be written

Mean planar grain area at 100 diameters
magnification = 2^{1-N} sq.in.

Figure 1 shows a small micro of steel which has A.S.T.M. grain size No. 1. The average planar grain area is 1 sq.in., but the grains may range in area from nearly 2 sq.in. down to nearly zero. (Under these actual circumstances it would appear that comparison charts showing a regular

W sizes No. $-\frac{1}{2}$, $\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$, and so on. Experience has shown that square and rectangular shapes are more useful than circles and hexagons, and two such standards of wide applicability are shown at full size in Fig. 2. The largest square in Fig. 2 has an area equal to size No. $-\frac{1}{2}$ and the next square has an area equal to size No. $+\frac{1}{2}$. (These values apply only when the magnification is 100.) Any grain, of whatever shape, with an area intermediate between these two squares is recorded as of size No. 0. The larger square for $W=5$ is the same size as the inside square for $W=4$; the smaller square for $W=5$ is the same size as the outer square for $W=6$, and so on. Therefore, to determine the size of any grain to the nearest whole number, it is compared to either the square or rectangular grid and two adjacent sizes are found, one of greater and one of lesser area than the grain; the size is then taken as the whole number lying between the adjacent areas. In other words, if the grain appears to have an area between the limits marked 5, either in the square or rectangular grid, it is recorded as $W=5$.

Distribution of spatial grain sizes is now found. Step A is counting the number of grains of each integral size and converting these figures to percentages of area. Counting is facilitated by photographing the specimen on a paper negative and marking the size of each grain on this print. Eastman Royal Bromide, E5, Double Weight Paper (formerly called PMC 9 Extra Contrast) is very satisfactory and requires only a short exposure. When a large number of specimens are to be measured, the making of such negatives requires little additional time and they furnish a permanent record of the appearance of the specimens. Any size area may be measured, but to insure a random sample an arbitrary region should be marked out which does not follow the grain boundaries, and which contains at least 200 grains. The size of all grains wholly or partly within this region is measured. The number of grains of each size is then counted, giving grains entirely within the region a weight of unity, and grains partly within the region a weight equal



to the fraction of the grain estimated visually to lie within the region.

An actual count of a certain specimen is as shown in the second column of Table I. To compute the relative area occupied by each size of planar grain (fourth column), the number of grains for each size is multiplied by a factor based on 1 for W size 6 (third column). The last column is then made up of the individual items in the fourth column divided by the total relative area.

Step B is the calculation of the distribution of spatial grains from the data of Table I, last column. It is not difficult to understand the principle on which this is based. From a mathematical analysis based on Scheil's experimental work, the distribution of planar grain sizes arising from an aggregate of grains having uniform volume (not necessarily shape) may be calculated. It may be shown that if the constant spatial size is, say, No. 1, then 72.8% of the area of a plane section would be occupied by grains of size

Table I—Computation of Distribution of Planar Grains

W SIZE No.	NUMBER OF GRAINS	FACTOR	RELATIVE AREA	PER CENT OF TOTAL AREA
1	9.9	$\times 32 =$	316.8	18.2
2	28.3	$\times 16 =$	452.8	28.5
3	56.6	$\times 8 =$	452.8	28.5
4	70.7	$\times 4 =$	282.8	17.7
5	42.4	$\times 2 =$	84.8	5.3
6 and higher	28.3	$\times 1 =$	28.3	1.8
			Total 1618.3	

No. 1, 20.3% by size No. 2, 5.1% by size No. 3, 1.3% by size No. 4, 0.4% by size No. 5 and 0.1% by size No. 6 and higher (see the last line in the table on the next page).

Furthermore, if spatial grains of size No. 1 occupy only a fraction, f , of the volume of the specimen, they will contribute planar grains of size No. 1 to the extent of $72.8f\%$ of the area of a plane section, of size No. 2 to the extent of $20.3f\%$, and so on. Thus, if the percentage of the area covered by planar grains of the smallest grain size number (largest grains) is measured experimentally, the percentage of the volume occupied by spatial grains of the same grain size number is given by a simple calculation, that is,

Table II—Subtraction Table for Spatial Calculations

SURFACE OCCUPIED BY PLANAR SIZE W	VOLUME OCCUPIED BY SPATIAL SIZE W	SURFACE OCCUPIED BY SMALLER PLANAR SIZE				
		W + 1	W + 2	W + 3	W + 4	W + 5 AND HIGHER
1%	1.4%	0.3%	0.1%	0%	0%	0%
2	2.8	0.6	0.1	0	0	0
3	4.1	0.8	0.2	0.1	0	0
4	5.5	1.1	0.3	0.1	0	0
5	6.9	1.4	0.4	0.1	0	0
6	8.2	1.7	0.4	0.1	0	0
7	9.6	2.0	0.5	0.1	0	0
8	11.0	2.2	0.6	0.2	0	0
9	12.3	2.5	0.6	0.2	0	0
10	13.8	2.8	0.7	0.2	0.1	0
11	15.2	3.1	0.8	0.2	0.1	0
12	16.4	3.3	0.8	0.2	0.1	0
13	17.8	3.6	0.9	0.2	0.1	0
14	19.3	3.9	1.0	0.3	0.1	0
15	20.6	4.2	1.1	0.3	0.1	0
16	22.0	4.5	1.1	0.3	0.1	0
17	23.3	4.7	1.2	0.3	0.1	0
18	24.7	5.0	1.3	0.3	0.1	0
19	26.1	5.3	1.3	0.4	0.1	0
20	27.5	5.6	1.4	0.4	0.1	0
21	28.8	5.8	1.5	0.4	0.1	0
22	30.1	6.1	1.5	0.4	0.1	0
23	31.5	6.4	1.6	0.4	0.1	0
24	32.9	6.7	1.7	0.4	0.1	0
25	34.4	7.0	1.7	0.5	0.1	0.1
26	35.7	7.2	1.8	0.5	0.1	0.1
27	37.1	7.5	1.9	0.5	0.1	0.1
28	38.5	7.8	2.0	0.5	0.1	0.1
29	39.8	8.1	2.0	0.5	0.1	0.1
30	41.2	8.3	2.1	0.6	0.1	0.1
31	42.7	8.6	2.2	0.6	0.2	0.1
32	44.0	8.9	2.2	0.6	0.2	0.1
33	45.4	9.2	2.3	0.6	0.2	0.1
34	46.8	9.5	2.4	0.6	0.2	0.1
35	48.0	9.7	2.4	0.6	0.2	0.1
36	49.5	10.0	2.5	0.7	0.2	0.1
37	50.9	10.3	2.6	0.7	0.2	0.1
38	52.3	10.6	2.7	0.7	0.2	0.1
39	53.5	10.8	2.7	0.7	0.2	0.1
40	54.9	11.1	2.8	0.7	0.2	0.1
41	56.4	11.4	2.9	0.8	0.2	0.1
42	57.7	11.7	2.9	0.8	0.2	0.1
43	59.1	12.0	3.0	0.8	0.2	0.1
44	60.4	12.2	3.1	0.8	0.2	0.1
45	61.7	12.5	3.1	0.8	0.2	0.1
46	63.1	12.8	3.2	0.8	0.2	0.1
47	64.6	13.1	3.3	0.9	0.2	0.1
48	65.9	13.3	3.4	0.9	0.2	0.1
49	67.2	13.6	3.4	0.9	0.2	0.1
50	68.6	13.9	3.5	0.9	0.2	0.1
51	70.0	14.2	3.6	0.9	0.2	0.1
52	71.5	14.5	3.6	1.0	0.3	0.1
53	72.8	14.7	3.7	1.0	0.3	0.1
54	74.2	15.0	3.8	1.0	0.3	0.1
55	75.5	15.3	3.8	1.0	0.3	0.1
56	76.9	15.6	3.9	1.0	0.3	0.1
57	78.2	15.8	4.0	1.0	0.3	0.1
58	79.6	16.1	4.0	1.1	0.3	0.1
59	81.0	16.4	4.1	1.1	0.3	0.1
60	82.4	16.7	4.2	1.1	0.3	0.1
61	83.8	17.0	4.3	1.1	0.3	0.1
62	85.0	17.2	4.3	1.1	0.3	0.1
63	86.5	17.5	4.4	1.2	0.3	0.1
64	87.9	17.8	4.5	1.2	0.3	0.1
65	89.2	18.1	4.5	1.2	0.3	0.1
66	90.5	18.3	4.6	1.2	0.3	0.1
67	91.9	18.6	4.7	1.2	0.3	0.1
68	93.2	18.9	4.7	1.2	0.3	0.1
69	94.7	19.2	4.8	1.3	0.3	0.1
70	96.1	19.5	4.9	1.3	0.3	0.1
71	94.4	19.7	5.0	1.3	0.3	0.1
72	98.8	20.0	5.0	1.3	0.4	0.1
73	100.2	20.3	5.1	1.3	0.4	0.1

division by 0.728. The rest of the area nominally occupied by planar grains of that size is in reality due to random intersections of smaller grains in the proportions mentioned in the preceding paragraph.

While the same calculation cannot be applied directly to planar grains of smaller size, since they arise partly from cutting large grains at some location other than their maximum cross-section, this difficulty is easily surmounted by carrying out the analysis in steps. After the amount of the largest spatial size is determined, its contribution to the distribution of planar grains of smaller size is calculated, using the percentages above noted. When the values thus found are subtracted from the observed distribution of the smaller planar grains, the result will be the planar distribution arising from all the spatial grains except those of the largest size. The remaining amount of the next largest planar grains can then be used to determine the amount of spatial grains of that size, and by simple repetition of these steps the whole analysis can be accomplished.

The data in Table I will now be analyzed as a specific example. But first it should be noted that the computation is greatly facilitated by a standard form (Fig. 3), and Table II wherein the percentages are listed. In this table, the entries on any row are treated as a group; the first entry is the percentage of the field occupied by the largest planar size present, the second entry is the percentage by volume of spatial grains of that grain size number, the third entry is the percentage of the field occupied by the next largest planar size present arising from these spatial grains, and so on. Since a suitable logarithmic relationship exists between the physical dimensions of a grain and its grain size number, the tabulated values apply equally well to any grain size.

Turn now to Fig. 3. Enter the distribution of planar sizes (last column of Table I) into line 1 of Fig. 3. The number 18.2, representing the percentage of the largest size, is then looked up in Table II, and by interpolation it is found that 25.0% of the volume of the specimen is of spatial grain size No. 1, and these grains contribute to the planar distribution 5.1% of

W. Planar Grain Size:	1	2	3	4	5	6 & Smaller	Line
Area, %:	18.2	28.5	28.5	17.7	5.3	1.8	1
	25.0	5.1	1.3	0.3	0.1	0.0	2
		23.4	27.2	17.4	5.2	1.8	3
		32.0	6.5	1.6	0.4	0.1	4
			20.7	15.8	4.8	1.7	5
			28.5	5.8	1.5	0.5	6
				10.0	3.3	1.2	7
				13.7	2.8	0.9	8
					0.5	0.5	9
					0.7	0.2	10
						0.1	11
						0.1	12

Fig. 3—Computation of the Relative Volumes of Spatial Grains of Various Sizes

size No. 2, 1.3% of size No. 3, 0.3% of size No. 4 and 0.1% of size No. 5. These figures are entered in line No. 2 (Fig. 3) and line No. 3 is obtained by subtraction. (Note that the first of the figures minus all the rest must always equal the number looked up, that is, $25.0 - 5.1 - 1.3 - 0.3 - 0.1 = 18.2$.)

The same procedure is now gone through for grain size 2. Look up 23.4 in Table II, and by interpolation it is found that this corresponds to 32.0% of the volume of the specimen, and that 6.5, 1.6, 0.4, and 0.1% of the planar areas must be deducted from the respective grain sizes, since those figures are due to the off-center intersections of spatial grains of size No. 2. These figures are entered in line No. 4 of Fig. 3; line No. 5 is had by subtraction, and the process is repeated to the end.

Since each subtraction removes one figure from the rows of Fig. 3, there may eventually be fewer spaces than there are entries in Table II. When this happens, all extra entries are lumped together in the last column of the form, since this represents size No. 6 and smaller.

Step C now follows, namely, the determination of the average spatial grain size from the percentage by volume just computed. This can be done in more than one way, but it has been assumed that the most significant value is

Table III—Computation of Grain Boundary Area

SPATIAL GRAIN SIZE	% BY VOLUME	FACTOR	GRAIN BOUNDARY AREA		
			RELATIVE AREA	% AREA	CUMULATIVE %
No. 1	25.0	1.000	25.0	14.8	14.8
2	32.0	1.414	45.3	26.7	41.5
3	28.5	2.000	57.0	33.5	75.0
4	13.7	2.828	38.8	22.9	97.9
5	0.7	4.000	2.8	1.7	99.6
6	0.1	5.656	0.6	0.4	100.0
Total relative area:			169.5		

obtained by averaging on the basis of spatial grain boundary area. Thus, an average will be determined such that a uniform specimen of that average size would have the same total grain boundary area per unit volume as there is in the specimen itself. This has been done by the computations in Table III.

The first and second columns, of course, are copied from the derived figures of Fig. 3. About the only thing in Table III that needs explanation is the "Factors" in the third column. Since the

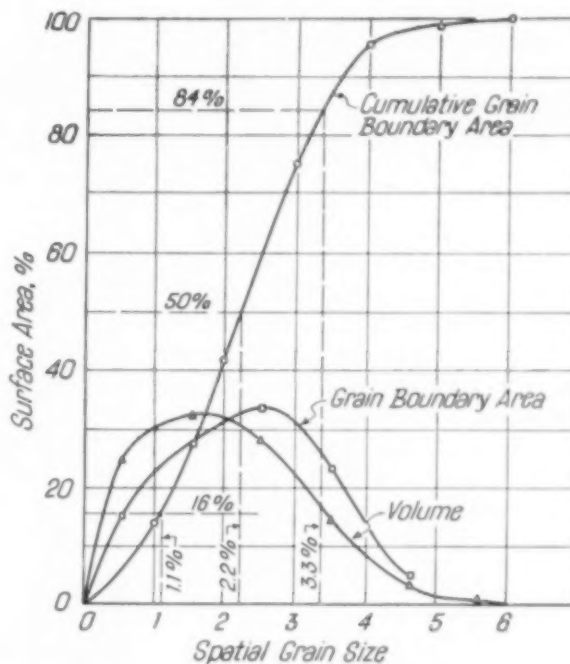


Fig. 4—Plot Showing Distribution of Spatial Grain Boundary Areas and Volumes. Mean spatial grain size = 2.2 ± 1.1

grain boundary area per unit volume is increased by a factor of $\sqrt{2}$ for an increase of one grain size number, these factors are simply a series of powers of $\sqrt{2}$, that is $(\sqrt{2})^0$, $(\sqrt{2})^1$, $(\sqrt{2})^2$, $(\sqrt{2})^3$,

The cumulative percentages are now plotted in Fig. 4 and a smooth curve drawn through the points. From this curve, the grain sizes corresponding to ordinates of 16, 50 and 84% are determined. The grain size at 50% is taken as the average spatial grain size, and one-half the difference between the size at 84 and 16% as the standard deviation. In the example worked out the spatial size is thus $No. 2.2 \pm 1.1$, meaning that the average spatial size is No. 2.2, and $84 - 16$ or 68% of the total

grain boundary area arises from grains of size No. 1.1 to 3.3.

While a plot of cumulative percentage of grain boundary area versus grain size is most satisfactory for determining the mean spatial grain size and the standard deviation, it is not a particularly graphic means for portraying the type of distribution of sizes present in the sample. For this purpose, it is better to plot the amount of each spatial size, either in terms of volume (second column of Table III) or grain boundary area (fifth column of Table III), as shown in Fig. 4. The specimen analyzed may be regarded as typical of those specimens showing a rather narrow and symmetrical distribution of spatial grain sizes.

It should be emphasized that all this discussion and analysis has to do with *cross-sectional areas* of different grains as intercepted by random planes. No method is at present available for obtaining a quantitative figure for area of grain surfaces, such as sq.in. of grain surface in 1 cu.in. of a sample of known spatial grain size distribution.

Whenever the spatial distribution of sizes is symmetrical with respect to the average size, and the standard deviation is not too large, the grain size number calculated by this procedure will agree closely with the A.S.T.M. number. The specimen analyzed was estimated to have an A.S.T.M. grain size of No. 2 to $2\frac{1}{2}$, perhaps No. $2\frac{1}{4}$. Under other circumstances, however, the agreement may be poor, and in any event the spatial grain size brings out information not disclosed by the A.S.T.M. number.

Common Difficulties

It should be emphasized at the outset that this analysis is for metal with equi-axed grains. It is obvious that in the extreme case of a "fibrous" metal, cut perpendicular to the fibers, all or nearly all the planar grains might be substantially equal in size, and such a microsection and this analysis would tell nothing about the spatial grains.

Structures will be found occasionally that are too coarse or too fine for convenient examination at 100 diameters. Measurements can then be made at another suitable magnification, the data taken as though the magnification were 100, and a correction applied at the very end of the

analysis according to the following schedule:

LINEAR MAGNIFICATION	CORRECTION TO GRAIN SIZE NUMBER
25	-4
50	-2
100	zero
200	+2
400	+4
800	+6

If the data for the example worked out in the body of this article had been taken from a micro made at 200 diameters magnification instead of 100, the mean spatial size would be 4.2 ± 1.1 instead of 2.2 ± 1.1 .

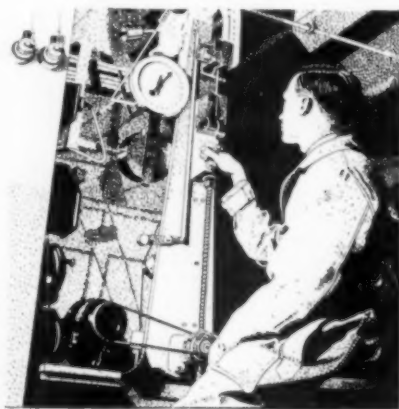
The only real difficulty likely to be experienced with the proposed analysis is an irregular behavior in the subtraction process. Irregularities may be expected if too few grains are examined to give a good statistical average, or if a

specimen has a duplex structure. In the latter case it may be found that grains near one average size occur as streaks or clusters in a background of grains of a quite different average size. It will then be most satisfactory to apply the analysis to each mean size separately, and to express the grain size of the whole specimen according to the principle illustrated in the following hypothetical example: 70% of 2.3 ± 1.3 and 30% of 6.8 ± 1.5 (streaks).

Troubles arising when analyzing insufficient data can obviously be avoided by taking a larger area of the specimen. Insufficient data will show up when plotting the cumulative grain boundary area; if one or more of the points fall away from a smooth curve, a larger number of grains should be counted. Unrecognized duplex structures also plot in an erratic manner.

Occasionally, difficulty arises in the subtraction process in that some of the percentages may come out negative. If the grains are approximately equi-axed, this may be taken to indicate a non-representative sample, and additional areas on the specimen should be counted. Alternatively, the cumulative percentages of areas measured on a random plane may be plotted, a smooth curve drawn and appropriate values taken from this curve for the subtraction process.

This whole calculation, exclusive of the taking of data, can be carried out by a trained worker in not over 10 min., even where insufficient data cause irregularities to appear.



Stress-Corrosion Cracking of 18-8

PHILADELPHIA, PA.

To the Readers of METAL PROGRESS:

We have carefully read Mr. Monypenny's letter in the November 1945 issue of *Metal Progress* on the "Stress-Corrosion Cracking of 18-8". Our experience during the past 15 years, in which we have fabricated many hundreds of tons of stainless steel of the 18-8 variety, indicates that when the metallurgy of this steel is accurately known and applied, the results are diametrically opposite to those described in that communication. It is certainly axiomatic that the successful use of any metal or alloy depends upon a thorough knowledge of its metallurgy. If this were not true, many of our most useful metals would long since be condemned as useless.

Mr. Monypenny has, in our opinion and experience, described a phenomenon which will only occur when the metallurgy of the steel is not understood and, because of this, certain conclusions and limitations of the use of the alloy are reached which are not in accordance with the facts.

The analyses of 18-8 stainless steel produced in this country falls within the following limits:

Carbon	0.15% max.
Manganese	0.20 to 2.5%
Phosphorus	0.04% max.
Sulphur	0.04%
Chromium	16.0 to 19.0%
Nickel	6.5 to 10.0%

As is true of many alloys, and particularly with those which cannot be heat treated (that is, quenched and drawn and for which, consequently, small changes can be made in the heat treatment to compensate for differences in the specific analysis) relatively small changes in the analysis of stainless steel make large differences in the metal's behavior. It is entirely incorrect to assume that a stainless steel having a chemical analysis in the low side of the range of acceptable analysis has physical properties and behaves after cold rolling or cold drawing in the same manner as a steel having an analysis in the high side of this range. The proper *balance* of the several constituents is just as important in this alloy as it is with the brasses, bronzes, or aluminum alloys, or with the so-called low alloy structural steels.

Let us examine, for example, two extremes. First would be a steel containing 19.0% chromium, 9.0% nickel, 0.50% manganese and 0.08% carbon. As may be seen, this falls within the high side of the established range. From a physico-chemical point of view, the steel is in comparatively stable equilibrium—that is, its austenite is stable as to carbon solubility and as to the effects of cold work. Consequently, considerable amounts of cold drawing can be performed without danger of stress cracking, and a corollary of this is that the steel must undergo a considerable amount of reduction by cold rolling in order to obtain a certain specified tensile strength. Such a steel would, then, be useful for deep drawing, but it would not be so useful for steel for structures wherein a specified strength and high ductility are required.

On the other hand, we may have a steel containing 17.0% chromium, 7.0% nickel, 1.25% manganese, and 0.12% carbon. Such a steel is, from a physico-chemical point of view, in metastable equilibrium, even though it is as stable as those alloys having slightly higher alloy content, from a practical point of view. A steel of this analysis is not so useful for deep drawing because its ductility is lower *after a given amount of deformation* than the more stable alloy, but it also has a very much higher ductility after having been cold rolled to a given tensile strength. That is to say, it requires much less reduction by cold rolling to obtain a given tensile strength in the metastable steel than is required for the more stable alloy. Consequently, the less stable austenitic steel is more ductile at a given cold rolled tensile strength than the more stable austenitic steel.

It is because of the failure to appreciate the significance of these important facts that, we believe, the British engineers have arrived at the conclusion that an astonishingly low limit of permissible tensile strength (157,000 psi.) is necessary for designs utilizing cold rolled stainless steel of 18-8 analysis. We have used and had in service for 15 years in America, in all kinds of atmospheric and other general service conditions, steel having a tensile strength of as high as 200,000 psi. with no failures of the material from stress cracking, or stress-corrosion cracking.

In this connection, it should be pointed out that there is a vast difference between specific

effects of stresses existent in a cold formed piece of steel. It makes a great difference on the results as to the magnitude and direction of these stresses. In general, it is *stress gradients* which do harm, and not simple unidirectional stresses. We have, for example, never observed stress cracking in cold rolled strip having a tensile strength as high as 225,000 psi., but we have experienced stress cracking (and it does not require the corrosion environment as mentioned by Mr. Monypenny to cause failures) in deep drawn stampings when 18-8 stainless steel of improper analysis has been used, or when the design of the stampings was made by those unfamiliar with the metallurgy of the steel. Incidentally, stress cracking of this same type may, under certain circumstances, occur after the deep drawing of *all* metals or alloys which recrystallize above atmospheric temperatures.

To summarize, stainless steel cold rolled to 185,000 psi. (minimum) having a proper balance of the alloy content has been used for 15 years in America for aircraft and other structures with no failures from stress cracking or stress-corrosion cracking. When deep drawn stampings are made from this steel in which high stress gradients and high tri-axial stresses occur, a different balance of the alloy content should be chosen and a different fabricating technique and design should be taken into consideration.

JOSEPH WINLOCK and PAUL NELSON
Chief Metallurgist and Metallurgist
Edward G. Budd Mfg. Co.

[EDITOR'S FOOTNOTE: Owing to the inordinate time required for a letter to get to England and a reply delivered, Mr. Monypenny's rejoinder — if he desires to make one — will be published later.]

Elastic Anisotropy in Electrical Strip Steel

BRACKENRIDGE, PA.

To the Readers of METAL PROGRESS:

Directional effects arising from preferred grain orientations (anisotropy) in rolled steels are well known, and are generally regarded as being undesirable. Stead's brittleness — or cleavage brittleness — and the formation of ears in cupping operations are the most frequent manifestations of crystalline anisotropy. They have often been described in the literature, with particular emphasis being placed on means of eliminating them and restoring the isotropic character generally desired in steel. A recent statement was by J. K. Stanley in *Metal Progress* for December 1944 ("Preferred Orientation — an Asset and a Liability").

It is not so well known that in some applications directional properties, particularly magnetic

properties, are highly desirable. In the field of sheet and strip steel for electrical purposes, considerable improvements in permeability and watt-loss have been brought about in recent years by the development of silicon steels having highly directional magnetic properties produced by suitable reductions and heat treatments. This situation was noted by The Editor in "Critical Points" last November. These directional properties have been recognized as being the result of preferred crystal orientation and, for those applications where a single direction of flux path is desirable, the crystal anisotropy of the steel has been developed to the fullest degree commercially practicable, having as an ultimate goal the magnetic characteristics of a properly oriented single crystal of silicon-iron. (See Smith, Garnet & Randall's U.S. Patent No. 1,915,766, and Goss's U.S. Patents No. 2,084,336 and 2,084,337.)

At present, the best of the highly oriented silicon steels are, in effect, aggregates of single crystals of silicon ferrite all of which have nearly the same crystal alignment. The preferred orientation consists of a cube edge parallel to the direction of rolling and a cube face at an angle of 45°

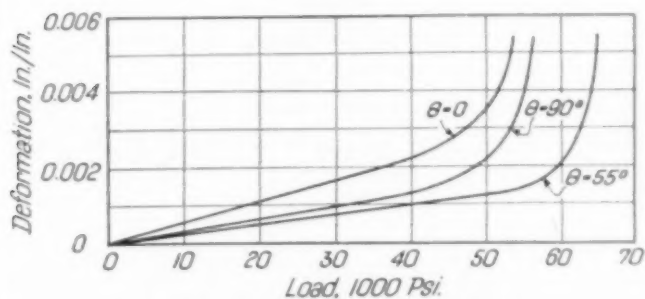
Variation in Tensile Properties With Angle to Rolling Direction

	ANGLE θ AND CRYSTALLOGRAPHIC DIRECTION		
	0° (100)	90° (110)	55° (111)
Elastic limit	41,000	42,000	54,000
Yield point	53,000	54,000	62,000
Ultimate strength	59,000	64,000	68,000
Elongation in 2 in.	7	33	2
Modulus of strip	$18.0 \cdot 10^6$	$30.0 \cdot 10^6$	$38.6 \cdot 10^6$
of single crystal	$19.0 \cdot 10^6$	$30.0 \cdot 10^6$	$41.0 \cdot 10^6$

to the plane of the sheet. As might be expected, such steels have unusual physical characteristics in addition to their unique magnetic properties. In the tests to be described, samples from a single piece of 3.20% silicon steel strip, 0.025 in. thick, were annealed at 2145° F. (1175° C.) in pure, dry hydrogen, and then tested in tension. A head speed of 0.025 in. per min. was maintained up to the yield point (0.2% offset), and 0.08 in. per min. from yield point to failure. Tuckerman optical strain gages were used to determine elongation. The tensile specimens were cut at angles of 0°, 90°, and 55° to rolling direction, which correspond to the (100), (110) and (111) directions respectively.

The stress-strain diagrams show that the sharply defined yield point usually associated with full-annealed steel is not present in this material.

Values for modulus of elasticity of the sheet as tested are perhaps the most noteworthy, since they correspond closely with the values reported by various observers for a single crystal of iron. Values for elongation also show the effect of strong orientation. Since slip in silicon ferrite is confined almost entirely to one plane, the manner in which plastic deformation occurs is very sharply restricted in this type of steel. The with-grain



Tensile Stress-Strain Diagram at Various Angles to the Rolling Direction

samples ($\Theta = 0^\circ$) elongated only 7% and the failure occurred by drawing down to a knife edge with no measurable reduction in width. The 90° samples stretched 33% over their entire length and failed in a 45° break across the width, no reduction in thickness occurring. The 55° specimens broke square after only 2% elongation.

The above observations are being reported as representing, to the writer's knowledge, the only case where single-crystal properties are approximated in a steel produced in considerable tonnage.

F. G. BENFORD
Research Laboratory
General Electric Co.

Can the Transformation Rate Be Speeded?

CALCUTTA, INDIA

To the Readers of METAL PROGRESS:

To a person trained in American methods India holds out such poor facilities for research that the best he can do is to indulge in some "imagineering". Two points in the May issue of the *Metal Progress* received here after a long delay suggest an interesting research problem.

In discussing the methods of interrupted quench A. H. Koch, in his paper on "Gas Furnaces for Interrupted Quenching", points out the virtues of isothermal quench to avoid the long holding times necessary for austempering. By withdrawing the steel from the austempering bath after a short time and immediately heating to a higher temperature the speed of transformation is con-

siderably increased. Unfortunately this method gives properties somewhat inferior to those obtained by the conventional austempering method. Some prior treatment that might reduce the austempering time, without affecting the properties in any way, is definitely indicated.

A clue to the possible solution may lie in the very interesting letter on "Incubation of Centers for Austenite Transformation" by the French metallurgist Albert Portevin. In the results of his quantitative study he states that incubation time (before the beginning of isothermal austenite transformation) is shortened if the steel is first quenched at some higher temperature and held there for a short time before transferring it to the isothermal bath.

Of course, in austempering the incubation period is very short compared to the time required for complete transformation, and quenching at a higher temperature prior to holding at the austempering temperature is not calculated to bring about any material reduction in the *total* time required for this treatment. However, it may be possible, by some prior treatment similar to Portevin's, to condition the austenite so that the rate of transformation during austempering is increased. If this increased rate of transformation is not accompanied by inferior physical properties, the main disadvantage connected with the austempering process will be eliminated.

Perhaps some research workers may already have thought of this problem.

D. P. ANTIA
Research Metallurgist
Indian Aluminium Co., Ltd.

Polishing Microspecimens for Production Control

NIAGARA FALLS, N. Y.

To the Readers of METAL PROGRESS:

C. J. Summerfield is to be congratulated on his skill in metallographic polishing if he can secure good results with the method described in August *Metal Progress*. Experience over many years, and in other laboratories than our own, has indicated plainly that it is very difficult to retain inclusions in a polished surface of steel when a treatment with alumina on *broadcloth* is relied on to remove the fine scratches from the last dry abrasive in preparation for polishing on the final wheel. Of course it can be done by an expert in this manner, but it will certainly lead to unfortunate results in the hands of a beginner. A slight modification will make it so much easier for an operator of only moderate skill to avoid trouble.

Way back in 1923 the subject of pitting of inclusions in metallographic specimens was discussed in *Chemical & Metallurgical Engineering* and elsewhere, and since then it has been quite generally recognized that this is most easily avoided by dry grinding, and using a fabric without nap (such as fine canvas, muslin, or "airplane fabric", or one impregnated with paraffin for the wet treatment between the finest dry abrasive and the final polish. This suggestion is incorporated in the A.S.T.M. tentative standard E3-44T, and in many books and other discussions of metallographic work.

With this simple modification of Mr. Summerfield's method, the hardening of specimens which he recommends for retaining inclusions should not be necessary; this is never done in our work, where a study of the inclusions is generally considered important in the majority of the specimens polished. Use of broadcloth, as he suggests, would be fatal for any metallographic study of graphite in cast iron.

GEO. F. COMSTOCK
Chief Metallurgist
The Titanium Alloy Mfg. Co.

Time-Temperature Relations in Tempering Mechanical and Forging Steels

A Note on the Data Sheet, page 96-B

ALL combinations of tempering time and tempering temperature that lie on the same hardness difference line in the chart making up the Data Sheet on page 96-B will produce the same hardness for a given steel and a given structure before tempering. (Note, however, that the chart has not been tested for high alloy steels such as stainless and high speed.)

Example: A 0.30% carbon steel tempered 10 hr. at 940° F. has a certain hardness. What tempering temperature would give this same hardness in 1 hr.?

Solution: In the chart, 10 hr. at 940° F. falls at "A", on "Hardness Differential Line 62". This line crosses 1 hr. at "B", which is at 1010° F.

For steels without large amounts of carbide-forming elements the difference in the hardness produced by two tempering treatments is approximately equal to the differential between the Rockwell C numbers given on the chart for the two treatments. This is not true, however, for hardnesses less than C-20 Rockwell or within 3 Rockwell C numbers of the hardness before tempering.

Example: A 0.30% carbon, 3% nickel steel tempered 10 hr. at 940° F. has a hardness of C-29

as determined experimentally. What would be the approximate hardness if the steel were tempered 2 hr. at 800° F.?

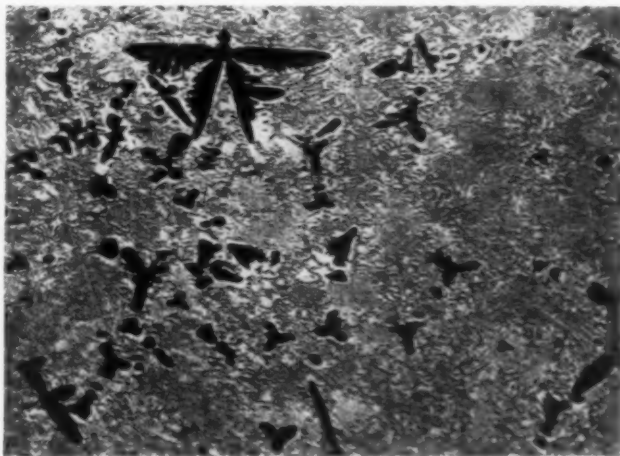
Solution: 10 hr. at 940° F. (Point "A") falls on line 62; 2 hr. at 800° F. (Point "C") falls on line 54; the differential is $62 - 54 = 8$. Hardness $= 8 + 29 = \text{Rockwell C-37}$.

A Flyer

COWLEY, OXFORD, ENGLAND

To the Readers of METAL PROGRESS:

In an age of aeronautical progress, the early efforts of the pioneers tend to be forgotten and it was with some delight that I observed a fossilized



structure in a cast section of a 50% silver solder containing copper, zinc, cadmium and silver.

A distinct resemblance to the early pioneer Bird Men can be seen in this otherwise typical dendritic structure.

G. A. KNIGHT
Assistant Metallurgist
Pressed Steel Co., Ltd.

Fractography

WEDNESBURY, STAFFORDSHIRE, ENGLAND

To the Readers of METAL PROGRESS:

Examination of cleavage facets on fractured metals has been claimed as a new tool for metallurgical research and control by C. A. Zapffe and M. Clogg in papers read before the 1944 convention of The American Society for Metals and recalled by the Editor of *Metal Progress* in his "Critical Points" for June 1945. These investigators have proposed that the term "fractography" should be applied to this technique. Amongst other things they have photographed the fractures of binary

NICKEL STEELS combine...

EXCEPTIONAL MECHANICAL *and* FABRICATING PROPERTIES



SAE 4330 Nickel chromium molybdenum alloy steel was adopted for Curtiss propeller blades because of its high strength, toughness and good workability, coupled with a wide safe heat-treating range.

High velocity cooling is not necessary to properly harden SAE 4330 for this application. There is no warping to correct by cold-straightening operations nor danger from subsequent stresses that might cause failure in service, because the slow transformation rate of this steel permits hardening to the required degree by die-quenching; thus consequent savings in time and labor, and a uniform final product are provided.



Curtiss Propeller Division of Curtiss-Wright Corporation, one of the largest producers of constant speed propellers, fabricates blades by welding two plates of SAE 4330 into a hollow unit that permits weight saving over solid blades of light metals.

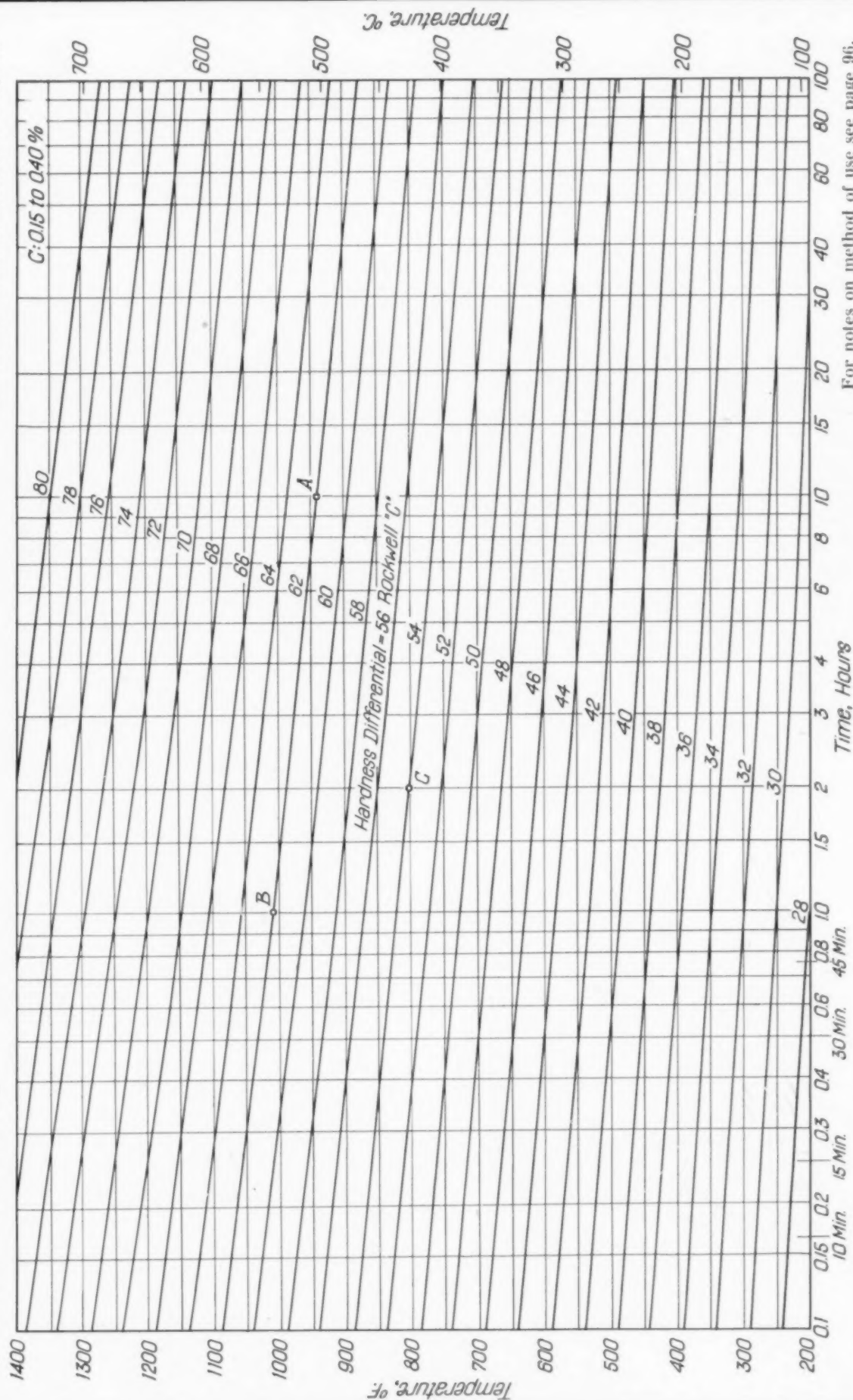
Inquiries on the use of Nickel alloy steels or other alloys containing Nickel in your products or equipment, are invited.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET
NEW YORK 5, N. Y.

Time-Temperature Relations in Tempering Mechanical and Forging Steels

By J. H. Hollomon and L. D. Jaffe

From A.I.M.E. Transactions, 1945, Vol. 162, p. 223



For notes on method of use see page 96.

iron-silicon alloys and have described certain structures as typical of the phases known to be present in these alloys. Many of the cleavage patterns shown in their two papers appear unique and quite unlike the known structural characteristics of these alloys as revealed by polishing and etching in a conventional manner.

We have examined by these same methods commercial 14.5% silicon-iron alloys and have obtained photomicrographs differing not greatly from those obtainable by ordinary polishing and etching methods. For example, Fig. 1 shows at a

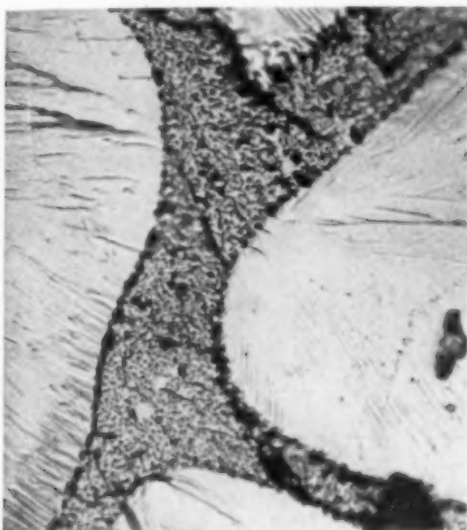


Fig. 1 — Fractograph

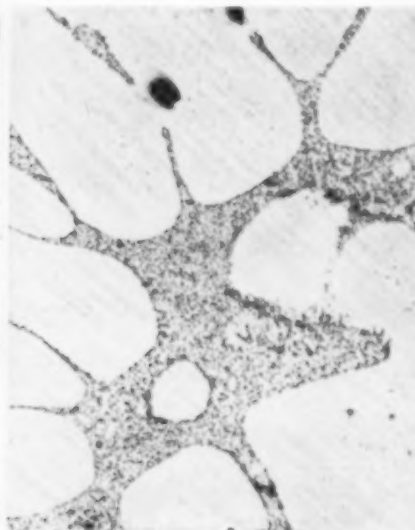


Fig. 2 — Micrograph

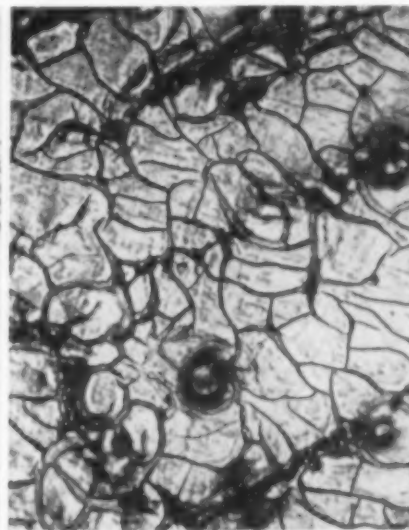


Fig. 3 — Cracks in Surface Oxide Film

Structures of a Silicon-Iron (14.5% Si, 0.45% C), Samples Prepared in Various Ways

magnification of 500 diameters a "fractograph" of a sample, vacuum melted and slowly cooled, of 14.5% silicon-iron containing 0.45% carbon. By way of comparison, Fig. 2 shows, at half the magnification, the same specimen prepared for examination according to the accepted methods of metallography. If the crystallographic surface markings of the silico-ferrite alpha phase be ignored there is a striking similarity between these two photographs.

The two papers by Zapffe and Clogg contain "fractographs" of an iron alloy with 11.84% Si and 0.038% C which bear little resemblance to the known microstructures. These authors imply that these very variable and somewhat indistinct markings, shown at magnifications up to 2000 diameters, are indicative of the complex nature of the silico-ferrite phase at this percentage of silicon. In support of this implication they publish photomicrographs polished and etched in 20% nitric acid, which show a major boundary and a network of sub-boundary markings. We are familiar with

this configuration ("barley shell structure") and have previously recognized it as being a false structure caused by the cracking of a thin oxide film on the etched specimen. A photograph (reprinted here as Fig. 3) showing a pseudo structure of this kind was included in our recent paper to the Iron and Steel Institute ("A Note on the Microstructure of High-Silicon Acid-Resisting Iron").

Similar misleading structures are very liable to be obtained if the film-forming tendencies of high-silicon irons are not understood, and if the etching reagent is not chosen with this in mind.

The mysterious markings in the fractographs should not be compared, therefore, with the sub-boundary markings as obtained after a nitric acid etch. The two sets of phenomena are different in origin, and in our opinion neither may be regarded as being evidence of any lack of homogeneity or of super-lattice formation in the alpha phase.

Of course the study of cleavage facets may be instructive, and not always misleading. In certain classes of hard brittle alloys some very useful information may be obtained from an intelligent examination of a fractograph. The fractograph of Fig. 1 is an example, wherein the reticular or eutectic type graphite, common in commercial alloys of this composition, is particularly well brought out. The minute graphite nodules at the boundary are shown to be larger than those in the interior of this phase, a fact which is not obvious from an examination of the photomicrograph, Fig. 2.

J. E. HURST R. V. RILEY
Technical Director and Metallurgist
Bradley & Foster, Ltd.

Centrifugal Casting of Gun Tubes

WATERVLIET, N. Y.

To the Readers of METAL PROGRESS:

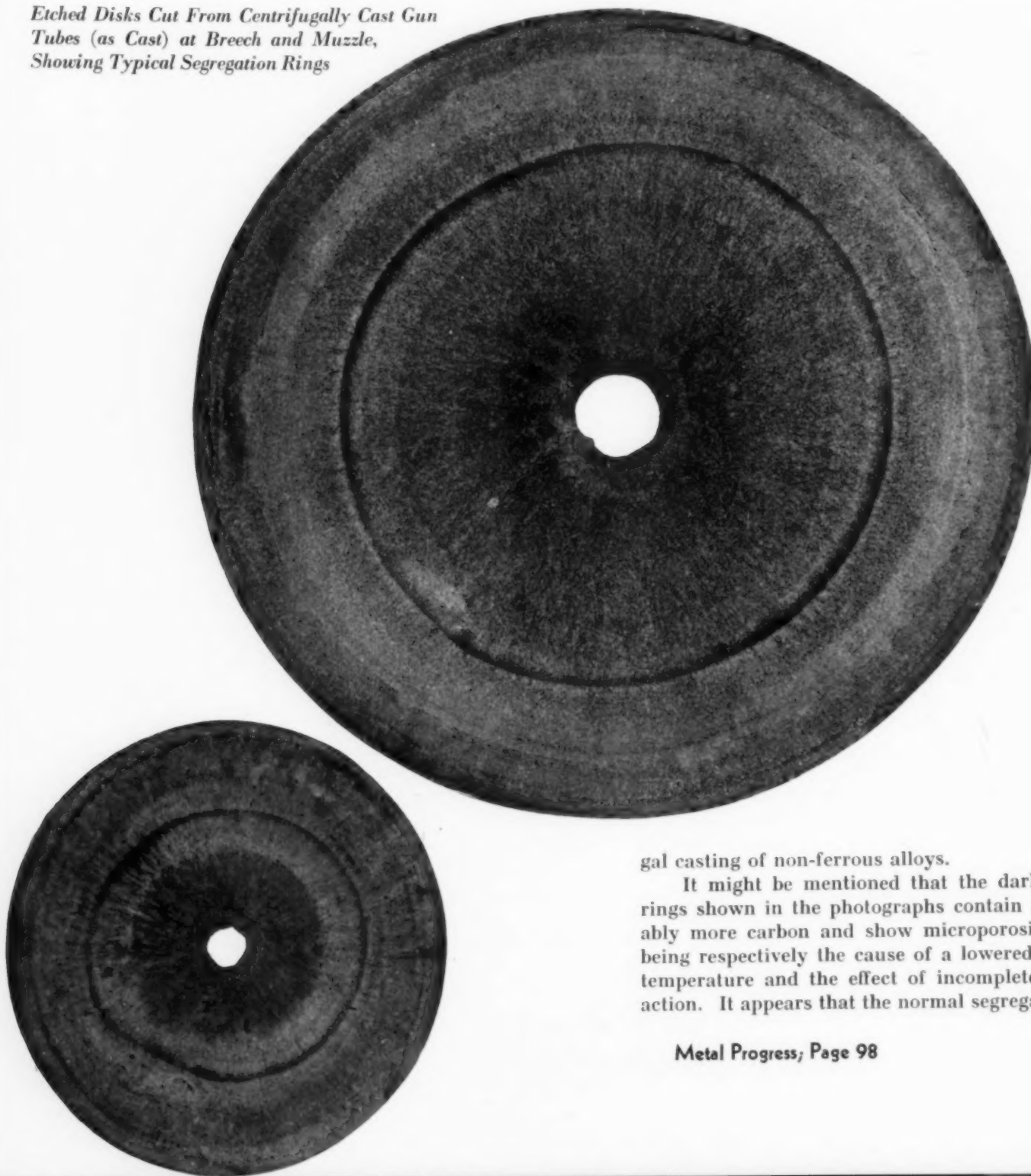
Mention of centrifugal casting at Watertown Arsenal and Dickson Gun Plant in "Critical Points" of the July 1945 *Metal Progress* was noted with much interest as I have been stationed at Watertown and am well acquainted at Dickson.

In your discussion of the process and of the structures disclosed by the deep etch test is a reference to "abrupt changes in structure" the exact causes of which are as yet unknown. If you

refer to macrostructures similar to the enclosed photographs it is hoped that the following may be of interest to some of your readers.

It was believed at Watertown that such macrostructures were due to unexpected vibration of the spinning mold which occurred during the solidification period. Confirmation was obtained by Alfred Smith, senior metallurgist, when similar banded structures were produced in conventional steel ingots of similar analysis by vibration of the molds during solidification. Further evidence that vibration promotes such banded structures has been obtained by observers at Woolwich Arsenal (England) in their work on centrifu-

Etched Disks Cut From Centrifugally Cast Gun Tubes (as Cast) at Breech and Muzzle, Showing Typical Segregation Rings



gal casting of non-ferrous alloys.

It might be mentioned that the dark-etching rings shown in the photographs contain considerably more carbon and show microporosity, these being respectively the cause of a lowered freezing temperature and the effect of incomplete feeding action. It appears that the normal segregation due

to selective freezing has been greatly increased by vibration and the thermal gradient, outside-to-center, is not steep enough to prevent the portions with lower melting temperature from being left behind in the progress of solidification.

JAMES A. CLARK
Captain, Ordnance Dept., U. S. Army
Watervliet Arsenal

Viscosity of Molten Aluminum and Its Alloys

MOSCOW, U.S.S.R.

To the Readers of METAL PROGRESS:

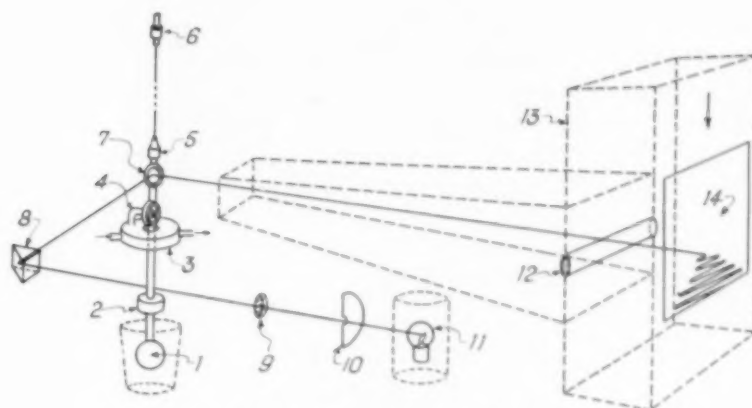
Viscosity of liquid metals has thus far been but little investigated on account of purely experimental difficulties. As a consequence there were no quantitative data up to the time of the present study for such an industrially important metal as aluminum, as well as for its major alloys.

To supply this data an extensive study of the viscosity of different aluminum alloys has been made in our laboratory by Messrs. Sergeiev and Polack. Their apparatus, shown in the sketch, comprised an oscillating ball in the liquid and determined the logarithmic decrement of damping for its torsional oscillation while suspended on a steel filament. The steel ball and its pivot immersed in the metal were protected against the attack of the molten aluminum by a layer of refractory coating not exceeding 0.1 mm. thick.

For calibrating, the viscosity coefficients of water and benzene were first determined. The data so obtained were in good agreement with the figures given by other experimenters.

Measurements for silumin (an Al-Si alloy with 12.3% Si, 0.44% Fe, 0.01% Mg) showed good reproducibility, which was, however, found to become considerably impaired at temperatures exceeding 1500° F. (800° C.) since at this point the protective flux of carnotite was sublimated and the oxide formed on the surface of the alloy increased the damping of the ball.

The obtained data at 1290° F. (700° C.) for the aluminum-silicon binary sys-

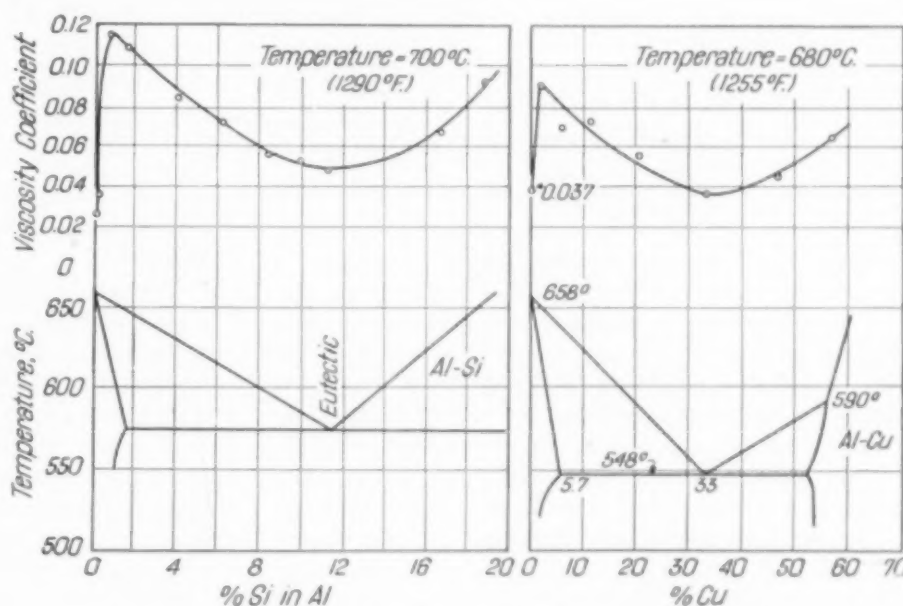


General Set-Up of Apparatus for Determination of Viscosity by the Damping, Oscillation Method

1—Ball. 2—Load. 3—Lid of furnace with cooler. 4—Copper heat absorber. 5 and 6—Clamps for filament. 7—Mirror. 8—Prism. 9—Lens. 10—Diaphragm. 11—Light source with lens. 12—Cylindrical lens in camera. 13—Camera. 14—Photographic plate moving with constant velocity.

tem are represented in one diagram, and for the aluminum-copper binary system at constant temperature of 1255° F. (680° C.) on the other.

There is a considerable increase of the viscosity of alloys with low concentrations of the second component, and a considerable decrease of the viscosity at the eutectic composition. This contradicts Sauerwald's data, which did not reveal the effect of the eutectic point on the viscosity of molten alloys. This discrepancy may be accounted for by the fact that he measured the viscosity of alloys at temperatures substantially higher than liquidus. It seems reasonable to assume that the



Viscosity of Molten Al-Si Alloys at 1290° F. (700° C.) and of Al-Cu Alloys at 1255° F. (680° C.) Is Quite High for the Respective Solid Solutions and Much Lower for the Eutectics

viscosity of alloys measured at temperatures near the freezing point, as was done in our laboratory, reflects the structural state of the liquid metal. This "structure" of the liquid may readily be destroyed as the temperature increases.

G. AKIMOW

Physical Metallurgy Laboratory
Research Institute for Aircraft Materials

Effects of Pressure and Temperature on Iron Powder Compacts

SCHENECTADY, N. Y.

To the Readers of METAL PROGRESS:

I was interested in the article by Messrs. Heath and Stetkewicz in the July 1945 issue of *Metal Progress* but cannot agree with all of their conclusions, for the data hold primarily for the particular material they used.

If the size and shape of a compact are to be controlled, it is a well known fact that there is an optimum pressure range for each material which will give least distortion and shrinkage upon sintering. This statement is only true, however, when the time and temperature of sintering are also given. Maximum densities are never attained by pressure alone. For example, reasonable pressures plus sintering temperatures close to the melting point give densities close to the theoretical for solid. For clean powders compacted at some optimum pressure the greatest shrinkage always occurs at temperatures close to the melting point, but these conditions are seldom used in practice to produce compacts of definite size and shape.

The authors' statement that production furnaces cannot be operated profitably at temperatures above 1100° C. (2000° F.) also neglects the fact that the whole industry making cemented carbides uses furnaces operating continuously at about 1500° C. (and sometimes higher) and produces hundreds of tons of material yearly. We may use sintering times of 32 to 64 hr. for iron compacts in experimentation and discover important facts, but practically everybody will agree that such long times are far too expensive for any practical applications yet found. If, however, it were necessary to sinter cemented carbides for such a period of time, I believe there would still be

no question as to the feasibility of the process.

It is my opinion that the authors are incorrect in interpreting the early slight loss in weight at the beginning of sintering (when the compact is heated in a hydrogen atmosphere) to "hydrogen loss" from the iron compact. This seems to be quite contrary to fact, for the decreases in weight and density are much more likely due to the loss of oxygen and not hydrogen, and the authors later explain this quite clearly.

An explanation of the increase in density of these iron compacts sintered at the $\alpha \rightarrow \gamma$ transformation temperature (a peak in the density-temperature curves) might be accounted for as follows: The change in lattice dimensions during the $\alpha \rightarrow \gamma$ transformation causes mobility and rearrangement of the atoms which results in a shrinkage of the compact as well as of the lattice. It is true that upon cooling from $\gamma \rightarrow \alpha$ that there would be an expansion, but the previous mobility at the transformation point has resulted in a greater

shrinkage than can easily be accounted for by the $\alpha \rightarrow \gamma$ transformation. This would account for the increase in density at temperatures below the peak. An increased diffusion of hydrogen into the compact at some stage during the atomic rearrangement would increase the amounts of steam formed with residual oxygen, and this steam, which cannot escape fast enough even in a fairly porous compact, blows it up, and might account for the decrease in density at the right of the peak (temperatures above the $\gamma \rightarrow \alpha$ transformation). I wonder if this

same effect could be produced with pure iron practically free from both oxide and carbon.

The explanation given by Messrs. Heath and Stetkewicz that trapped gases are the sole cause for bursting of compacts seems to be a little misleading. If there is a bulge in the ends or any part of the compact, I would agree that sintering had progressed at the outside sufficiently to seal in the gas and the bulge was caused by the resulting pressure of the expanded gas. In these particular experiments I should say it was steam. The cracks or fissures formed where extremely high pressures are used might be due to trapped gas if the pressure for compacting is applied rapidly in nicely fitted dies, but if the pressure is applied slowly in dies that are not so closely fitted,

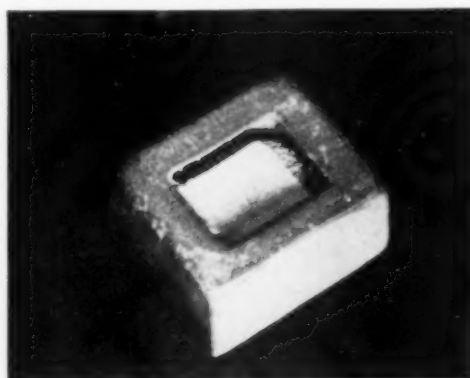


Fig. 1 — Bottom View of Rectangular Compact (1.5X) of Alloy Powder Whose Core Separated From the Box-Like Outside Case During Sintering

the fractures may be due to shear stresses between strata of different density.

This applies to compacts made in collapsible dies where the compacts are not ejected by the plunger. They may be found in compacts made of relatively coarse powders (-100 mesh) where the powders are relatively hard to begin with and pressures are of the order of 60,000 psi. They may be visible directly after compacting. In some work done in General Electric's laboratory, powders of -200 mesh, pressed in an evacuated chamber where pressures were not applied until after evacuation, appeared perfect after removal from the container and the dies, but upon sintering the same troublesome cracks at right angles to the direction of applied pressure appeared. These compacts were pressed at 400,000 psi. The powders were freshly reduced and clean. No blisters occurred. These cracks in compacts pressed at extremely high pressures are sometimes visible immediately after removal from the die.

We have never found blisters in iron compacts sintered in hydrogen if the iron powders are freshly reduced, clean, and free from oxides. Diffusion of hydrogen into the compact reacts so rapidly with oxygen, forming steam, that it blows bubbles or forms blisters on the samples at high temperatures.

It is my belief that the cause of many of these cracks that plague the makers of parts from metal powder is due to shear stresses between strata of different densities, and I wish to offer as evidence the photograph shown in Fig. 1.

This is a rectangular sintered compact in which the top of the specimen in the photograph was the bottom when compacted. It was originally one compact; during sintering the core broke away from the box-like shell. The taper on the compact after sintering reveals the difference in pressure applied in a mold having only one movable plunger. The compacting pressure was about 60,000 psi. The top of the compact as shown in the photograph was resting on a flat boat during the sintering operation. During sintering, a change in composition of the outer shell resulted in a material that shrinks at a lower rate than the core. The resulting stresses from this differential shrinkage caused the core to shear itself loose from the shell like a pea in a pod.

This experience (and others) indicates that at very high compacting pressures the load must be applied slowly. The compact actually creaks at intervals, loud enough to be heard as the load is applied, indicating that the pressure has overcome the side wall friction of strata nearest the plunger and some of the pressure is then being transmitted to those volumes closer to the center. It is between

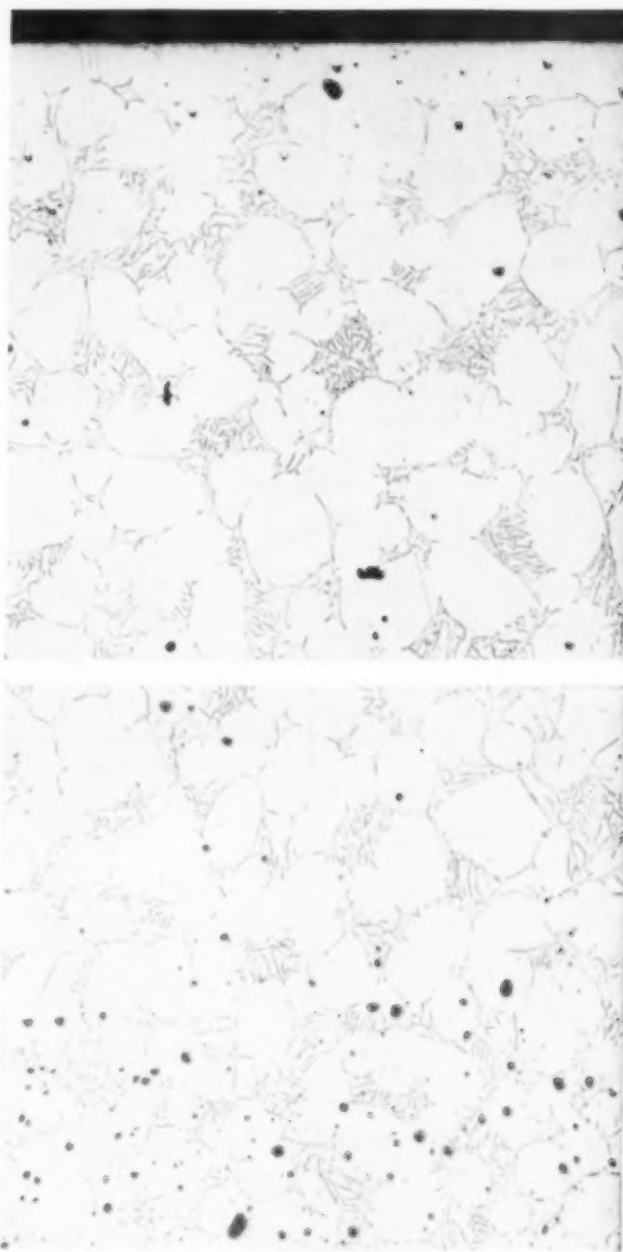


Fig. 2 and 3—Edge and Center (at 100 Diameters) of 18-8 Compact Sintered Unusually Long and at Unusually High Temperature, Thus Indicating That Voids Are Eliminated Progressively From Surface Toward Center by Processes of Recrystallization and Diffusion

these strata that fracture occurs either upon release of the pressure or during sintering.

Sintered compacts may in fact have trapped gas in them, but still cause no trouble upon sintering. As proof of this I submit the photomicrographs of Fig. 2 and 3 of 18-8 sintered at 2500° F. (1375° C.) in pure dry hydrogen for 24 hr. after pressing at about 60,000 psi. This 18-8 powder was -100+200 mesh and had considerable porosity as pressed. The powder was made by disintegrating heat treated 18-8 sheet or scrap. Elimination of the voids progressed from the outside inward, for Fig. 2 shows a cross-section of the outside of the compact while Fig. 3 shows a cross-section at

the center. Elimination of the voids has occurred through recrystallization and diffusion. If the sintering time is extended long enough, the compact finally attains the density of wrought material and is practically free from voids. This would not be true if the powders were oxidized and steam was formed after diffusion of hydrogen through the sintered outside shell.

The structure of this sintered material is quite abnormal for 18-8, but is probably caused by long time sintering at such a high temperature.

F. C. KELLEY
Research Laboratory
General Electric Co.

Authors' Closure

We find that Dr. Kelley agrees with us to a greater extent than indicated by his comments when it is kept in mind that our paper deals with iron powder, not cemented carbides or 18-8.

When we stated that production furnaces cannot be operated "profitably" at temperatures above 2000° F. (1100° C.) and that sintering times of 32 to 64 hr. cannot be considered in mass production, it applies to iron powder compacts. Thus, with the temperature and time limited for iron powder to compete with other methods of production, we believe he will agree that high density will be obtained with high pressures, since we are nowhere near the melting point of iron.

The use of the term "hydrogen loss" to designate the loss on heating in hydrogen is admittedly a poor choice. It was used because it is a term used by one of the large producers of metal powders. Of course, most of the loss is due to oxygen, plus other gases. This is one of the items which needs a specific term and a number have been suggested, but none accepted universally.

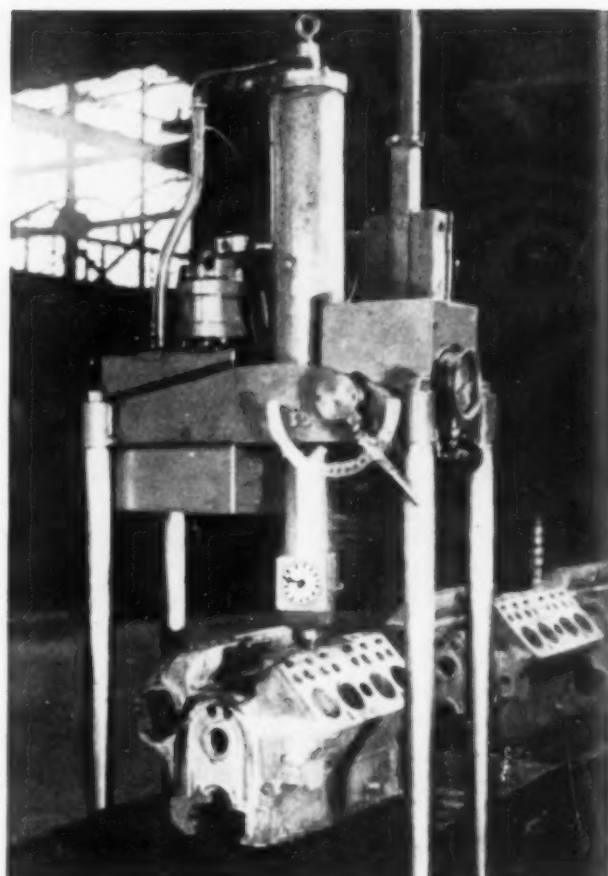
We appreciate having Dr. Kelley's explanation of the increase in density at the $\alpha \rightarrow \gamma$ transformation, although we cannot be sure of the rapid formation of steam, since at those high temperatures steam is also decomposed, so that a number of factors (such as moisture content of the hydrogen source, lubricant used, and so on) must be taken into consideration. Also our compacts were heated slowly.

Power-Operated Brinell Machines

AMHERST, MASS.

To the Readers of METAL PROGRESS:

Various notes have appeared in this publication describing adaptations of standard hardness machines or special applications of the indentation principle for the routine inspection of ordnance parts, but nothing has so far been said about one of the most useful, namely, the power-operated Brinell machines. This equipment has been used very extensively during the war on projectiles and bombs above 20-mm. caliber, as well as in engine plants, where the accompanying illustration was taken. The view shows a line of



Four-Post Type of Direct Reading, Power-Operated Brinell Machine, Over Roller Table. The long stroke in the plunger enables the inspector to test large or small parts in any order without handling. Courtesy, Detroit Testing Machine Co.

engine blocks coming along under the indenter of one of these machines. The direct reading feature is used; no microscope is required for measuring the diameter of the indentation, except for an occasional check on the tolerance settings. This direct reading feature is of no advantage on miscellaneous work; it is strictly a production set-up, and not an attachment.

The load control valves are so arranged that the ball contacts the work and approximately half the test load (1500 kg.) is used as a pre-load. At this point, the indicating gage on the front of the machine becomes operative and further penetration, beyond the pre-load point, is registered. The purpose of the pre-load, of course, is to break down surface conditions and "set" the specimen firmly on the support.

It is not advisable to place the actual hardness numbers on the dial. The actual hardness numbers would be correct only on ground, flat surfaces and very rigid seats or anvils. Actual numbers would therefore be misleading. As a result a dial

graduated arbitrarily from 0 to 100, with definite "go" and "no go" limits, is used.

In setting the tolerance hands, a spot is ground or polished on the first piece to be tested, and its actual Brinell hardness is read in the conventional manner. The part is then put in the power-operated machine and a second test made on the rough surface immediately adjacent to the smoothed spot and dial reading noted. It is then a simple matter to set the tolerance hands at the desired limits.

There has been considerable misunderstanding in regard to the so-called direct reading machines. In the strict sense of the word, it is direct reading only on a comparison basis, but it works well as a production check. Of course the standard 3000-kg. load and the microscope may be used at any time.

S. R. WILLIAMS

Fayerweather Laboratory of Physics
Amherst College

Improvements in Manual Arc Welding

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

Improvements in arc welding electrodes which speed the work greatly and improve the quality of the joint are worthy of comment. The whole program is a logical outcome of efforts to remove the "bottlenecks" of labor and electrode shortages arising early in our vastly expanded program of ship and ordnance production. "Foolproof" electrodes were necessary; better fitting of parts to be welded and better assembly fixtures were also helpful; precise instruction sheets for sequence of welding were necessary to control warpage and distortion. All this resulted in two important advantages, namely, the use of larger electrodes and heavier currents. Thus the rate at which the metal was deposited jumped from about 1 lb. per hr. to approximately 4 for manual welding, and many times that for automatic. Production methods using fixtures and special handling equipment resulted in an increase from 10 to 50% in the time that the arc was in use. The cost for identical work was often cut as much as 90%.

It was found that as the speed of arc travel was increased more energy became available to melt the base metal. Take, for example, a common T-joint made in $\frac{1}{2}$ -in. plate with $\frac{1}{4}$ -in. electrode of American Welding Society's E-6020 classification, and 300 amperes current. Fillet welds made under these conditions at 5 in. per min. did not "penetrate" to the corner of the the joint; the "throat" or maximum thickness of the fused metal in the fillet was only $\frac{1}{4}$ in. When the arc speed

was increased to 12 in. per min., other conditions remaining the same, the parent metal was fused $\frac{1}{32}$ in. beyond the corner and the "throat" of the weld increased to $\frac{9}{32}$ in. The higher arc speed necessitated electrodes which would have better and faster slag coverage, capable of carrying higher currents. When $\frac{1}{4}$ -in. electrodes of this sort were produced a speed of 12 in. per min. and current of 350 amperes was permissible. In this case, the parent metal was fused $\frac{1}{8}$ in. beyond the corner to give a $\frac{5}{16}$ -in. throat. The joint strength is now 32,000 lb. per lineal inch as compared to 27,000 lb. per inch for the conventional joint made at 5 in. per min. A saving of 50% was made in the deposited metal with 50% less man-hours, the cost of the joint being 40% less with 25% more strength.

It did not take long for welding engineers to recognize the possibilities of applying this same technique to butt joints where it now produces 100% welds with a minimum of preparation. The older conventional joint in $\frac{3}{8}$ -in. plate, for example, required the edges to be beveled to a 60° Vee, and assembled with $\frac{1}{16}$ -in. gap at the root—an expensive preparatory and set-up job. The welder was then able to finish 2 in. of joint per min. With the new, high speed electrodes, the plates need not be beveled, merely butted. He welds from both sides, the penetration being ample to go to the center, and he completes 9 in. of joint per min. The amount of electrode metal deposited is reduced 50% and the man-hours 78%.

This technique necessitates close engineering control and design from the point of view of fabrication. The tendency is to use larger electrodes and higher current with ever increasing arc speed, as electrodes are improved to give better slag covering characteristics and better bead appearance (which is a factor dictating top speed at present). Thus, the full power of the arc was made available to melt the parent metal to give greater penetration instead of being used on piled-up weld metal which tended to roll ahead of the arc. This new technique makes use of higher arc speeds, shorter arcs, and larger currents, necessitating larger capacity welding machines, but results in easier welding. The greater penetration results in savings due to fewer pounds of electrode purchased per foot of weld for horizontal and flat fillets and for the butt joints where square edges can be used. The elimination of plate beveling, frequent increase in arc time, and decrease in spacing between plates, will minimize costs of weld metal, labor, electrodes and power.

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Annealing Cycles

Effect of Cooling Transformation Upon Subsequent Isothermal Reactions

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ISOTHERMAL transformation diagrams, commonly known as S-curves, are of undisputed value for predicting transformation behavior of steels of various types, and these diagrams deserve their present wide usage. Recent experiences of the writers in the application of such data, however, have shown that under some circumstances the user of S-curves is likely to arrive at the wrong conclusions unless his interpretation pays adequate attention to the differences between the time-temperature cycle he desires to analyze and the time-temperature cycles whereon the S-curve is based. What must not be forgotten is that the isothermal diagrams chart the behavior of small specimens which are quenched almost instantaneously to the various transformation temperatures, where they are held for various lengths of time, again to be quenched at the end of each desired time interval to "fix" the structure. This program studies the progress of isothermal transformation at various appropriate (but stationary) temperatures. Unless the actual time-temperature cycles are reasonably like those of the small specimens, the structure obtained in practice may be vastly different from that which had been predicted from the S-curve.

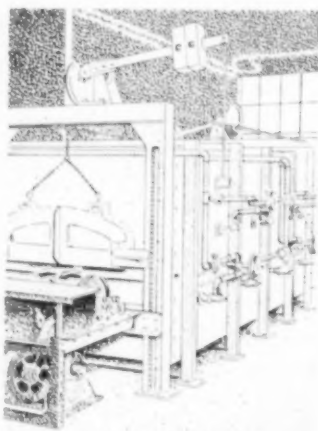
Two such instances will be reviewed in the following. They will be used to illustrate the current tendencies to draw conclusions from isothermal diagrams that are somewhat too far-reaching — overlooking, for instance, the difference between the transformation of a postheated weldment which has cooled slowly through the range of ferrite precipitation and that of a

mere sliver of steel which has been quenched to its transformation temperature.

It will be noted that if a metallurgist bases his analysis of a *hardening* cycle on isothermal transformation, the results will be in error on the safe side, since the beginning times of isothermal reactions are shorter than the time required for a reaction to start during a continuous cooling cycle. (See References 1 and 2.) This discussion, therefore, is not concerned with applications that depend on the time-temperature curve of beginning reactions, but with those applications where the results depend upon the *completion* of transformation. Such applications can best be exemplified by so-called isothermal annealing cycles, where complete transformation of the austenite is desired at a constant subcritical temperature and — a second instance — by postheating of weldments to exclude martensite from the final microstructure. The source of errors to be pointed out (and discussed briefly) pertains to hypo-eutectoid steels of medium or high hardenability. Steels with low hardenability or materials whose carbon content approaches or exceeds the eutectoid composition have not been included in this review.

Isothermal Annealing

The first indication that the S-curve cannot be used with complete disregard of any transformation which may have occurred during cooling to the isotherm was obtained during an investigation of spheroidization by Payson's method (Reference 3) of a steel of the following composition: 0.22% C,

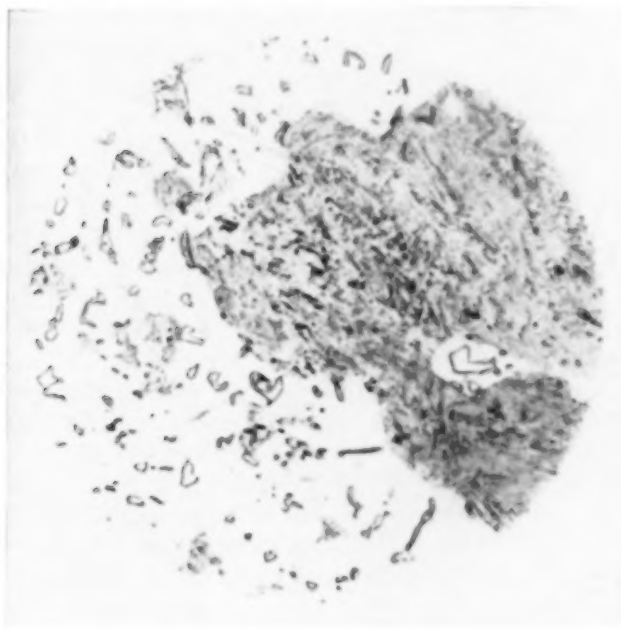


0.98% Mn, 0.49% Si, 0.95% Cr, 2.17% Ni and 0.47% Mo.

The time required for complete isothermal spheroidization turned out to be excessive, over 20% of the austenite having failed to transform after 48 hr. at 1240° F. (see Fig. 1). We then attempted to transform the steel by cooling it to 675° F. where the S-curve for a reasonably similar steel (S.A.E. 4340) indicated that transformation should occur in less than 2 hr. We held the steel 12 hr. at 675° F. and then reheated it and held it at 1270° F. for 36 hr. Surprisingly, some austenite still was retained, as shown by Fig. 2.

The structure of Fig. 1 was not unexpected since the slope of the end-of-transformation curve is very gradual at 1240° F. Hence, this curve per-

Fig. 1 — Structure of Over-Alloyed Steel Resembling S.A.E. 4320. Austenitized at 1375° F. for 12 hr., transformed isothermally 48 hr. at 1240° F. About 80% transformed. All micros etched in aqueous solution of picric acid as noted in text. Magnification 2000 ×



mits one to make only an approximation of the total transformation time. In addition to this, the somewhat higher alloy content of the steel actually under test would retard the transformation beyond that found for the standard S.A.E. 4340.

The significance of Fig. 2, however, is that austenite transformation was incomplete after 12 hr. holding at 675° F., followed by 36 hr. at 1270° F., even though the S.A.E. 4340 S-curve (Reference 7) indicates that *complete* transformation should require less than 2 hr. at 675° F. It might be objected that our reheating was too high, being

above A_{c1} . However we proved that A_{c1} of our steel was not below 1290° F. by the heating of fully annealed specimens to various temperatures, 10° F. apart, for 2 hr. and quenching. When A_{c1} was exceeded the hardness began to increase and martensite began to appear in the microstructure.

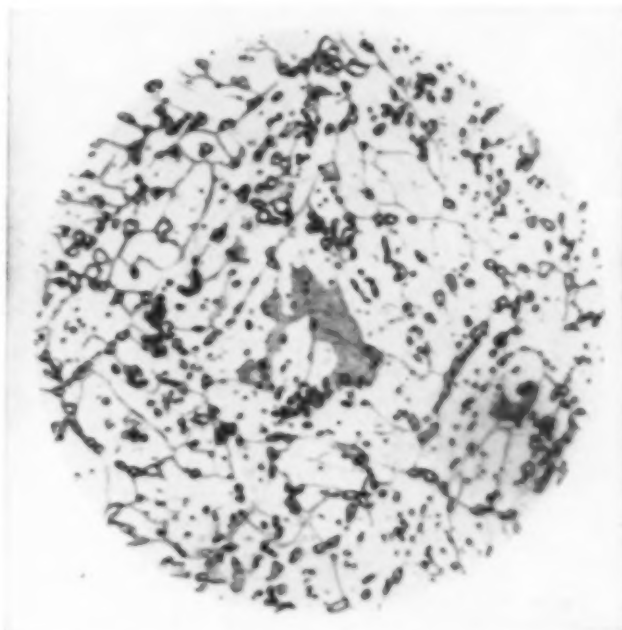


Fig. 2 — Same Steel as in Fig. 1, Austenitized at 1375° F. for 12 Hr., Transformed Isothermally 12 Hr. at 675 and 36 Hr. at 1270° F. About 97% transformed. 2000 ×

Postheating of Weldments

The second and really convincing demonstration that transformation during cooling changes the isothermal transformation behavior was given by numerous studies of test weldments, $\frac{7}{16}$ by 4 by 18 in. in size, which were postheated for various periods up to 6 hr. at 600, 650, 700, and 800° F. immediately upon welding to prevent the formation of martensite, as recommended by References 4, 5, and 6. The majority of these weldments were prepared from S.A.E. 4330 steel. Upon slow cooling from the postheating temperature, all contained considerable percentages of martensite even though very small specimens of the same material upon quenching to the isotherm from 1700° F. did transform completely at 600° F. in 30 min. and at 700° F. in 60 min., corroborating the S.A.E. 4340 S-curve of Reference 7. (See the left curve of Fig. 3.)

Subsequently, $\frac{1}{2}$ -in. cubes of the same steel were austenitized at 1700° F. and transformed for various lengths of time in a furnace maintained at 700° F. These specimens showed the same

transformation behavior as the weldments in spite of somewhat faster cooling to the transformation temperature. Figure 3 shows the completely transformed structures resulting from isothermal transformation after quenching to the isotherm (locations spotted by small circles on the diagram), contrasting with the incompletely transformed structures in the samples cooled in the

furnace to the same temperature and held considerably longer time (locations spotted by small triangles).

To summarize: Isothermally quenched microspecimens of S.A.E. 4330 steel transformed completely to bainite at 600° F. in 30 min. and at 700° F. in 60 min., but weldments and microspecimens (½-in. cubes) which were cooled slowly to 600 or

to 700° F. and held up to 6 and 12 hr., respectively, were but partially transformed. The slow cooled, isothermally transformed steel showed a large proportion of pro-eutectoid ferrite, not found in the specimens which were quenched to the isotherm, as shown by Fig. 3.

Conclusions

The reason for this departure of slow cooled, isothermally transformed steel from true S-curve behavior is, of course, perfectly clear. Austenite which has precipitated ferrite during slow cooling will not transform in the same time as austenite which has not precipitated ferrite (having been quenched to the isotherm). The former austenite will be richer in carbon than the latter—the more so, the more slowly it has cooled. Whether the steel be S.A.E. 4320 or 4330, sufficiently slow cooling will cause the austenite to approach the eutectoid composition through the rejection of ferrite, before it has begun to react isothermally to bainite. Under these conditions, the time required for the remaining high carbon austenite of either of these steels to transform completely to bainite is likely to be more nearly expressed by the S.A.E.

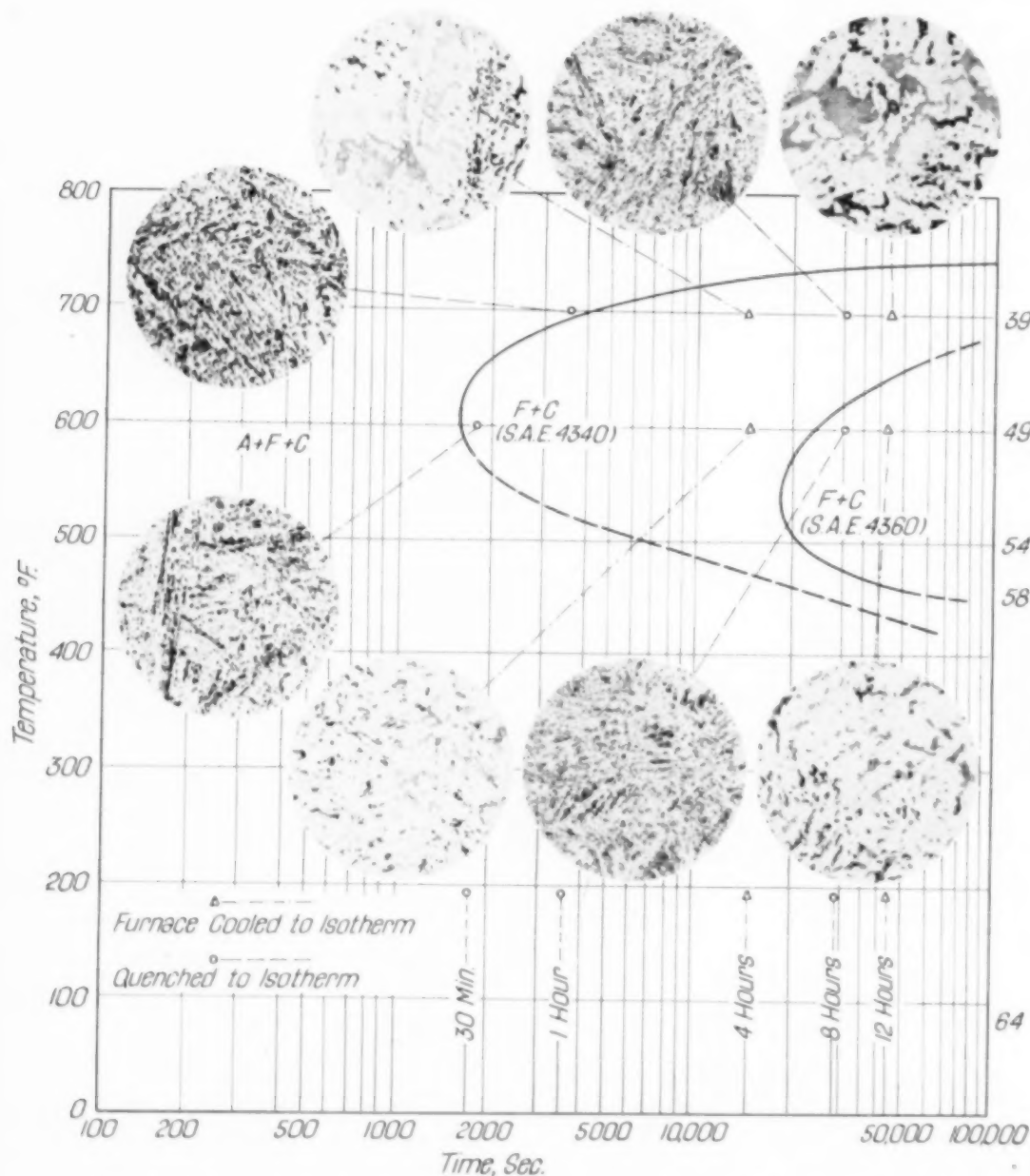


Fig. 3—Curves Showing End of Isothermal Transformation in Bainite Reaction Range for S.A.E. 4340 and 4360. From United States Steel's "Atlas of Isothermal Transformation Diagrams". Note that the specimens quenched to the isotherm corroborate the end-of-reaction curve for S.A.E. 4340 steel. However, the specimens which were furnace cooled to the isotherm reacted even more slowly than the isothermally transformed S.A.E. 4360. Gray patches on the photomicrographs of furnace cooled specimens are martensite (untransformed austenite at the isotherm). Micros at 1000 ×

4370 curve than by the 4320, 4330, or even the 4340 S-curves.

These conclusions can also be expressed in another way in terms of the concept of "bainite hardenability" introduced by Hollomon and Jaffe, (Reference 8). Thus, the formation of pro-eutectoid ferrite tends greatly to increase the bainite hardenability. On the other hand, formation of pearlite during the cooling of a hypo-eutectoid steel would have to be preceded by the precipitation of ferrite,

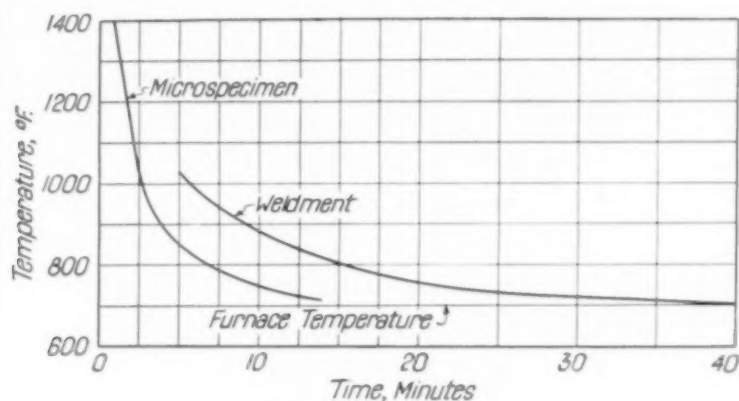


Fig. 4 — Cooling Curve for Weldment Cooled From 1030° F. for Postheating at 700° F. and for Microspecimen Austenitized at 1700° F. and Transformed in a Furnace Maintained at 700° F.

and it is quite doubtful, therefore, that pearlite would have any intrinsic effect on the bainite hardenability.

In Fig. 3 the end-of-reaction curves were taken from the S-curves for S.A.E. 4340 and 4360 given in Reference 7. The inserted micrographs are ours and show the results of isothermal transformation of S.A.E. 4330, either quenched to the isotherm or slow cooled to the isotherm. Note that the quenched specimens corroborate the S-curve but the slow cooled structures contain untransformed areas that indicate the end-of-transformation boundary should be shifted to the

right. The cooling curves of the weldments and the slow cooled specimens used to obtain the micrographs appear in Fig. 4.

It would appear, therefore, that the S-curves will most certainly be an unreliable guide for predicting the structures after continuous cooling of a material of medium or high hardenability, unless conditions causing departures such as these from true S-curve behavior be carefully considered. The S-curve can be used with confidence to predict the beginning of reaction, since reactions upon slow cooling set in more tardily than shown by the curve; but to predict the time for ending of reactions from isothermal diagrams is often an undertaking of dubious value. There are many possible combinations of steels and cooling cycles which cannot be analyzed readily on the basis of a single isothermal diagram because the composition of the reacting austenite varies gradually through a wide range, and depends upon the characteristics of the cooling cycle as well as upon the composition of the material.

Picric Acid Etching Reagent

In this investigation, as in many others, the paramount necessity was to obtain contrast between ferrite and martensite. With the common reagents, such as 4% picral or 2% nital, this objective could not be reached without seriously over-etching the entire structure.

Our associate, W. C. Coons, found that an aqueous solution of picric acid produced excellent results, and it is described herewith in the hope that other investigators may benefit from its use.

Composition: 0.5 g. picric acid; 100 ml. distilled water.

Temperature of Solution: Etch in solution maintained at 160 to 170° F.

Time of Etching: 15 to 20 sec. The time may be varied to produce proper contrast. To reveal presence of martensite, etch lightly. ☼

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Oxygen in Steel

A New Etching Reagent for the Detection of Oxygen Segregations in Steel

By Leslie Fine

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YEARS ago the problem of phosphorus segregations in steel was of considerable importance. With the development of Stead's reagent for its detection, an etch was available for the metallographers of that day to locate such segregations and helped to eliminate them. Today, metallographers seldom see a sample of steel showing undue segregations except where phosphorus is deliberately used as an alloying agent.

In the same way, oxygen segregations have been strongly suspected under certain conditions, but a metallographical detective tool has been lacking. The alkaline chromate etch discussed in this article is believed to be just such a reagent to locate oxygen segregations in low alloy, medium carbon steels.

The Menasco Mfg. Co. instituted an investigation of the various defects which caused magnaflux rejections in various forgings. Metallographical examinations of sections through areas of magnetic leakage usually revealed the defects. Occasionally the cause could not be located; these samples did contain, however, some small globular inclusions which appeared to be iron oxides, but it was believed that these small inclusions in themselves could not cause the magnetic indications. A nital etch of the area in question gave a vague indication that something more serious was the cause of trouble. Figures 1 and 2 show a macrograph of one such indication and a micrograph of a cross-section through the same.

We suspected from the fine oxide inclusions that this area might be one of high oxygen concentration. However, we could not prove it. The fact that strong alkaline solutions with the addition of certain anions will produce an oxidized film on the surface of steel has been known for a long time (see, for example, the article by Messrs. Weisberg and Parker on "Advantages and Limita-

tions of Black Oxide Coatings" in *Product Engineering* for May 1943). It has also been observed by those engaged in industrial application of black oxide coatings that this oxide film is inhibited from forming by the presence of oxides already on the surface. With this in mind we tried some strong alkaline solutions containing particular anions, thus attempting to form an oxide coating on the surface in general, but not in an area which had been previously oxidized. An alkaline chromate solution was tried (after much experimentation with other alkaline solutions) and produced the results shown in Fig. 3 of the identical area shown in Fig. 2.

Although the above piece of evidence tended to confirm suspicions regarding the nature of the defect, it was decided that much more proof would have to be obtained before the etch could be accepted as a criterion of the presence of dissolved oxygen, or iron oxides in steel in relatively large amounts.

When steel is exposed to air at high temperatures, iron oxide inclusions may be formed beneath the scaled surface. Therefore, it was felt that in such a sample dissolved iron oxides and oxygen are present in addition to the observable iron oxide inclusions. If such *dissolved* oxides or oxygen could be detected by the alkaline chromate etch, this would be a convincing proof of the reagent's effectiveness.

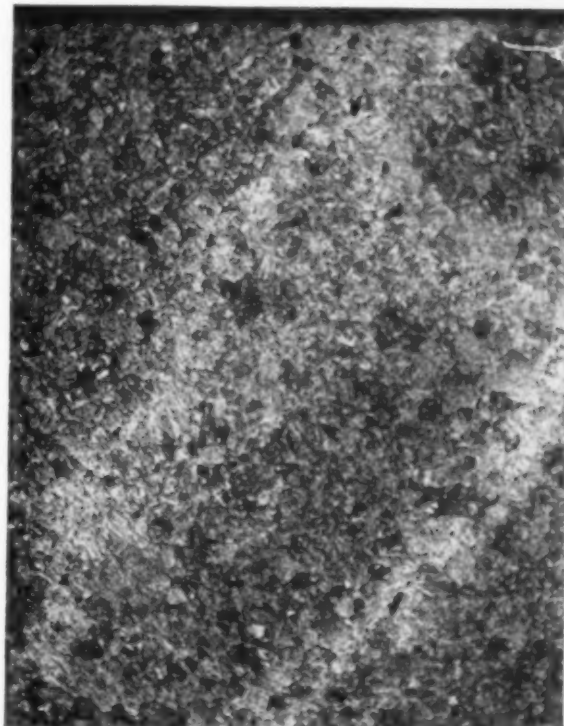
Experiments of this nature were carried out by heating small samples of NE8630 in air for 8 min. at 1800, 2100 and 2300° F. respectively. The samples were air cooled and examined under the microscope. Such samples must be cooled fairly rapidly. If they are permitted to cool with the furnace the scaling reaction (which continues at much lower temperatures than the diffusion mechanism) completely scales away all evidence

Fig. 1 (Above) — Magnaflux Indication, Full Size, on a Finely Machined Forging. Fig. 2 (Left, Below) — Cross-Section Through the Area of Magnetic Leakage. The inclusions do not appear to be of sufficient magnitude to cause the indication. Some segregation in the steel can also be noted. Nital etch, 100X. Fig. 3 (Right, Below) — Same Area Shown in Fig. 2. Alkaline chromate etch, 100X. Segregation of oxygen in the steel appears in very sharp contrast



of the diffusion which had occurred at the higher temperatures.

Figures 4, 5 and 6 give a general idea of the change in reaction with increasing temperature, time of heating remaining constant. At 1800° F. the reaction has formed a thin continuous white-etching zone containing numerous fine dotted inclusions; there are also many small intergranular penetrations into the steel. At 2100° F. the reaction formed a much wider zone of oxidized material containing the same finely dotted inclusions and only a trace (in the upper and lower ends



of the micro) of any intergranular penetration. At 2300° F. the zone is still wider and there is no longer any intergranular attack. The width of the oxidized or white-etching zone formed at 2300° F. was approximately 0.001 in. It is interesting to note that the dotted inclusions are larger in size and fewer in number at 2300 than at 2100° F.

It was desirable to have some knowledge of the amount of oxygen diffused into the steel in such samples as shown in Fig. 6. If the oxygen diffused into the steel is small in amount, then

Fig. 4, 5, 6 — NE 8630 Heated in Air 8 Min. at 1800, 2100 and 2300° F. and Air Cooled. Alkaline chromate etch (at 750 diameters) shows oxygen-impregnated layer as light band. Surface at right in all views

Fig. 7—Area Similar to Fig. 6 Etched 10 Min. in Alcoholic HCl. Gray inclusions are dissolved, indicating predominance of FeO in their constitution. 500×



the small dotted oxide inclusions in the white-etching zone could account for all of it. On the other hand, if the amount diffused into the steel were large it would almost necessarily mean that some of the oxygen must be present as dissolved oxygen or oxides and not as oxide inclusions alone. Since it is so difficult to determine oxygen directly by analysis and since the author was not interested in an accurate determination, it was decided that the iron in the white zone should be determined, and the difference (after taking the other elements into consideration) would be assumed to be a good approximation of the amount of oxygen present. The chemical work was conducted as follows:

Freshly machined coupons of NE8630 weighing 10 to 15 g. were treated (that is, oxidized to

this is considered to be oxygen.

The small dotted inclusions in the white zone were identified by the etch tests suggested by the Handbook. They were strongly attacked after 10 min. in alcoholic HCl, and therefore are FeO inclusions (with some MnO inclusions probably

present). Figure 7 shows an area quite similar to Fig. 6 after attack by HCl.

In addition to the heatings in air several experiments were conducted at high temperatures in commercially pure oxygen and commercially pure nitrogen. The results achieved in pure oxygen were identical in appearance to those already illustrated. When heating in oxygen it was necessary to use a low rate of flow to avoid burning up the specimens and to avoid excessive scaling.

As would be expected, the experiments conducted in pure nitrogen produced no white-etching zone or observable reaction products.

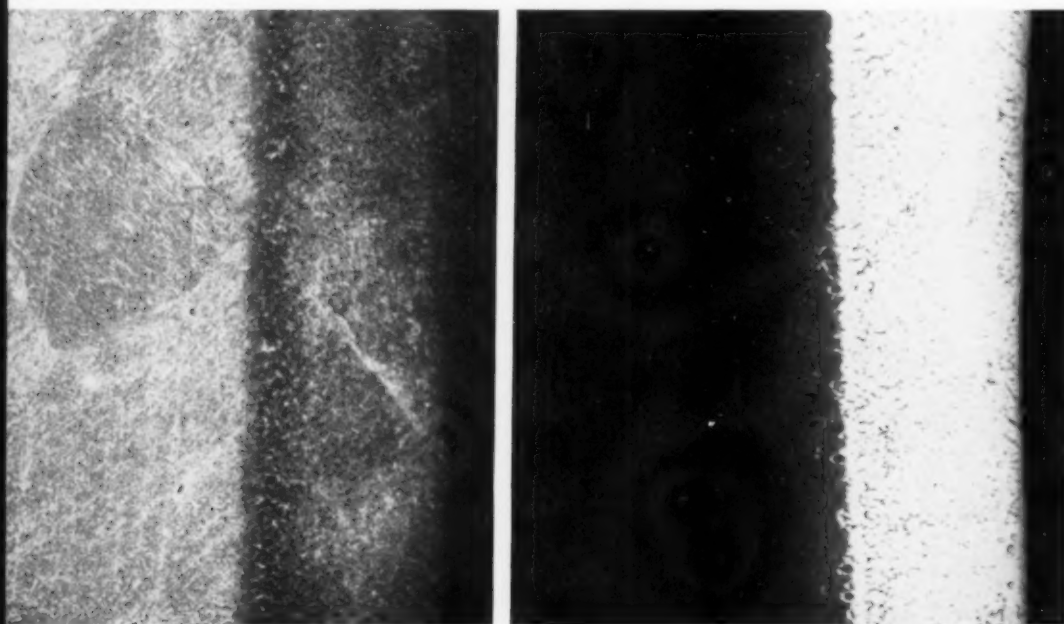


Fig. 8 and 9—Oxy-Acetylene Torch Cut Surface of a Steel Casting, Etched With Nital at Left, and Same Area Etched With Alkaline Chromate. Magnification 100 diameters

Several other practical evidences are submitted to show that the alkaline chromate solution is sensitive to oxygen segregations in steel. For example, the torch-cut surface of a sample of steel almost invariably shows a white-etching area. Refer to Fig. 8 and 9. Such a surface has been in the presence of a large excess of oxygen in an oxy-acetylene cutting flame at a high temperature. The surface zone shown in Fig. 8 and the metal beneath it consist of slightly tempered martensite. The darkening of the martensite at the surface is due to the presence of high oxygen. (It has been a general observation of the author that when a sample having a region of high oxygen content and containing carbon is quenched to martensite and then drawn not above 600° F., the martensite in the oxygenated area is of a darker coloration when etched in nital. It has also been observed that high oxygen has a strong tendency to force the carbon out of these affected areas, and unless the oxygen is introduced rapidly and the sample is cooled fairly rapidly, the affected areas will contain very little carbon.)

Another interesting example of the use of the etch, and which is at the same time an illustration of some of the known peculiarities of a high oxygen content on carburizing characteristics, is

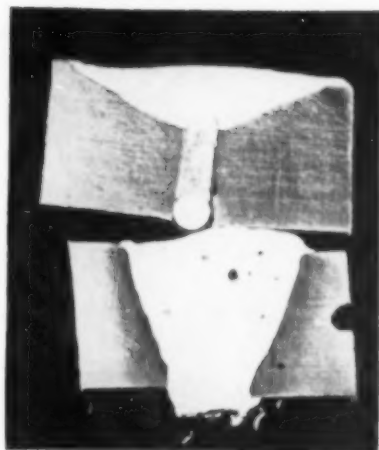


Fig. 10 (Upper) — A Cross-Section of an Oxy-Acetylene Weld. (The white circular section appearing at the base of the weld is a piece of non-ferrous wire.) (Lower) A cross-section of a metallic arc weld made with a bare electrode of low carbon content. Both samples etched with alkaline chromate solution

shown by a pair of samples of S.A.E. 1020, one torch cut to produce a white-zoned area and the other saw cut. Both samples were then box carburized in the same run. During carburization and subsequent cooling an atmosphere of methanol, burned with a deficiency of oxygen, was maintained in the furnace—in addition to the carburizing medium within the box. Nevertheless, the torch cut sample after carburizing shows a strongly decarburized surface where the white-etching zone had been produced (high in oxygen). The sample of the same steel which was not torch cut and which was run as a control during carburizing showed normal carburizing characteristics, that is, eutectoid carbon concentration to the very surface.

In the metallography of welding, the alkaline chromate solution can find considerable application. This will be shown in detail in an article in *Metal Progress* next month, by C. H. Maak, A. R. Ozanich and the author ("Metallurgical Aspects of High Quality Pressure Welded Joints for Landing

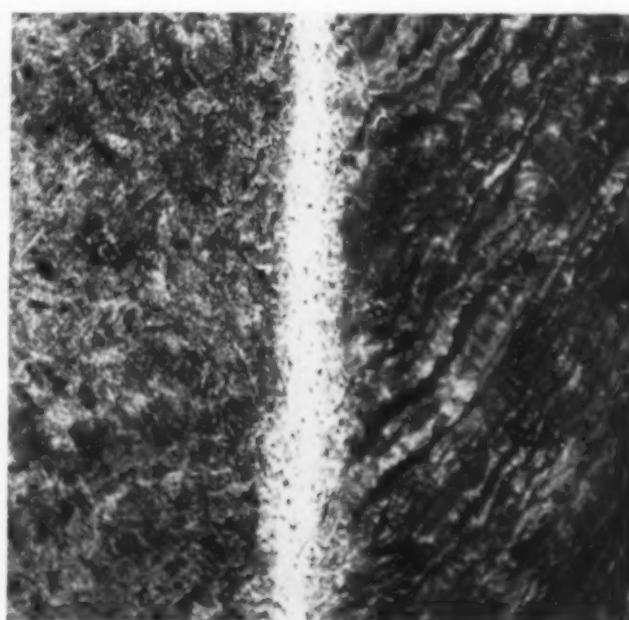


Fig. 11 and 12 — Weld Plane of a Flash Weld, Etched With Nital at Left and With Alkaline Chromate at Right. Same area. 100×

Gear"), in which special application of the alkaline chromate solution to the pressure weld process used at Menasco Mfg. Co. is discussed. For our present purpose a few prints are submitted to illustrate applications to other types of welding and at the same time to serve as additional evidence of the validity of the claims made for the etching solution.

Figure 10 is a macrograph of an oxy-acetylene weld and arc weld made with bare rod metallic electrode, both etched in the alkaline chromate solution. The deposited metal shows a much lighter coloration, as would be anticipated by the presence of oxygen during welding. Shielded metallic arc welds did not reveal any white areas when subjected to the above etch.

Figures 11 and 12 show the weld plane of a flash weld etched respectively in nital and in the alkaline chromate solution. The metal is in the as-welded condition. The same area is shown in both. Note the sharp thin layer of metal high in oxygen, not suggested in any way in Fig. 11.

Preparation of Etch and Advice Regarding Its Use

The alkaline chromate etch is prepared and used* in the following manner:

Weigh out 16 g. of chromic acid. Add 145 ml. of distilled water. To the above solution, slowly add 80 g. of caustic soda. Heat to boiling and keep the solution boiling at 118° to 120° C. Place the sample to be etched into the boiling solution for 7 to 20 min. Remove sample quickly and place into a container of cold water. Rinse in a stream of cold water, then rinse in alcohol. Remove alcohol by rubbing the surface gently with a piece of soft tissue. The sample is then ready for micro-examination.

A word of caution: The caustic soda should be added very slowly. At least a minimum of 5 min. should be allowed for this operation or else the beaker should be placed in a cold water bath for rapid cooling. Due to the strong exothermic reactions involved, the solution tends to boil over during preparation.

Samples mounted in either bakelite or lucite work very satisfactorily. For best results the

*A patent to cover the salient features has been applied for.

bakelite mount should be prepared by heating to 175° C. at 5000-psi. pressure. It has frequently been found that bakelite mounts prepared at 160° C. showed inferior resistance to the strongly alkaline solution.

Because sodium carbonate forms from the CO₂ in the air, it has been found desirable to use a fresh preparation each day.

The various constituents found in steel do not

etch at the same rate in alkaline chromate. Martensite is the most rapidly attacked and ferrite the most slowly. Even ferrite, however, etches much more rapidly than do zones of high oxygen content. The other constituents fall somewhere in between. The mass of the sample will affect the etching time to a large extent, since the sample itself must be heated as well as the solution. Variations in the composition of the solution are possible within certain limits and will still produce satisfactory results. This means that very accurate weighings are unnecessary.

Some of the applications of the etch are receiving further investigation. It has been found that the etch will delineate quite clearly the depth of a nitrided case. Brittleness in welds is being correlated to white-etching zones that are present, and some very remarkable results have been uncovered. For example, welded specimens containing such zones, and successfully passing static physical tests, have been known to fail under very low impact. Abnormal carburizing characteristics have, in several instances, been traceable to the presence of white-etching zones. Also, the carburizing of white-zoned areas (the samples then being air cooled) has led to the discovery of a needle-like structure which may shed some light on the old controversy regarding "nitride needles" present in welds. A paper is planned for publication on this interesting development.

The manner in which oxygen will apparently force carbon out of an oxygen-rich area is also being investigated. It has been noted that when a white-zoned area containing carbon is annealed, the carbon is forced out of this area and frequently "piles up" immediately adjacent to it. No explanation for this occurrence is put forward at this time. It is possible that some new evidence about the difference between "abnormal" and "normal" steels (noted by McQuaid many years ago) can be secured with the help of this reagent.



The Upright Type of Microscope in Metallography

By J. R. Vilella

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SINCE the introduction of the inverted microscope the use of the standard upright type for metallographic work has declined to such extent that today it finds itself allocated chiefly to routine inspection and student work. The inverted type is generally preferred because by merely placing the specimen on the stage, polished surface down, the necessary perpendicularity to the optical axis is attained, and because it can be equipped with a horizontal camera that is out of the way when the instrument is used for visual observation. Since these are important advantages, the manufacturers of microscopes have concentrated their best efforts on the development of the inverted type, and by frequently adding improvements and refinements have evolved an elaborate instrument of high optical and mechanical excellence. However, there are certain characteristics of the upright microscope, not found in the inverted type, which make the upright instrument a valuable metallographic microscope. In fact, recent experience has shown that because of these characteristics a majority of the workers prefer to use the upright instrument for much of their work when both upright and inverted instruments of good quality are available, for the following reasons:

1. It is more comfortable to use, particularly for extended observations. The ability to rest the elbows on the table while examining a specimen makes it far more comfortable to use than an instrument in which the elbows have to be raised to operate either the fine adjustment or the mechanical stage. Likewise, the fact that the instrument can be tilted to any desired angle permits the observer, regardless of his height, to maintain a comfortable posture. This is important in laboratories where one microscope is used by several workers.

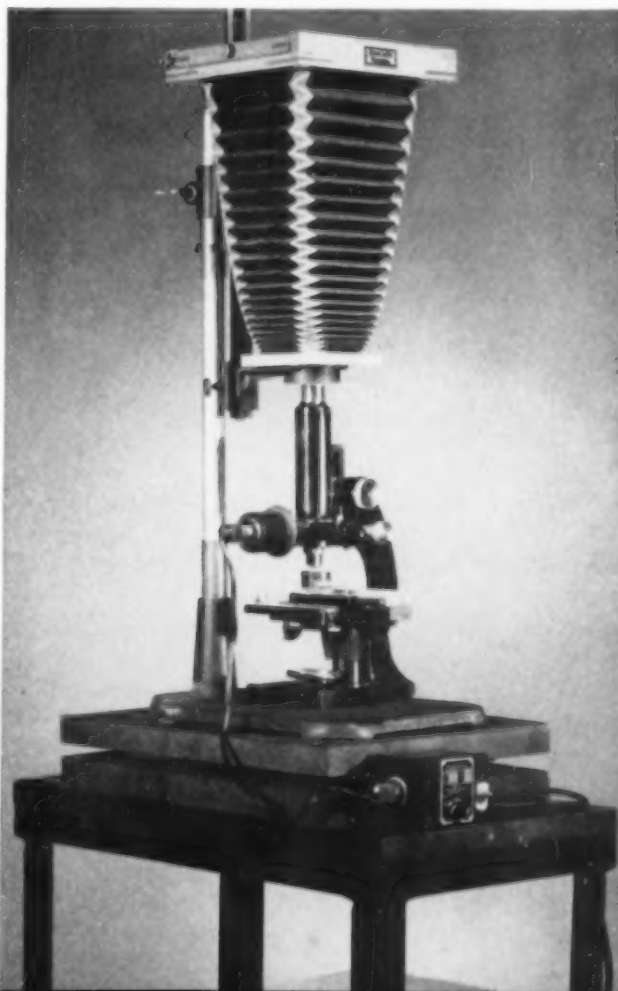
2. The mechanical stage available for upright microscopes has a greater traverse than the stage generally built on inverted instruments. This is important in the examination of large specimens, particularly those exhibiting continuous changes of structure such as occur in welds, hardenability specimens, gradient cooled sections, and many others which are best studied when the transition of structure is observed uninterrupted.

3. The fact that the specimen lies polished-surface-up on the microscope permits the observer to see what part of it is under the objective or, if several specimens are assembled in a clamp or in a plastic mount, to see what individual specimen is being examined. This is difficult to do on the inverted microscope, and unfortunately is something that has to be done frequently.

4. A source of illumination of the proper intensity attached to the tube of the microscope and permanently aligned, so that an adequately illuminated field of view is secured by merely turning on the electric current, is a convenience seldom found in inverted instruments.

These advantages and conveniences of the upright microscope would be of minor importance if the image produced by the inverted instrument

Microscope and Camera Ready for Photomicrography



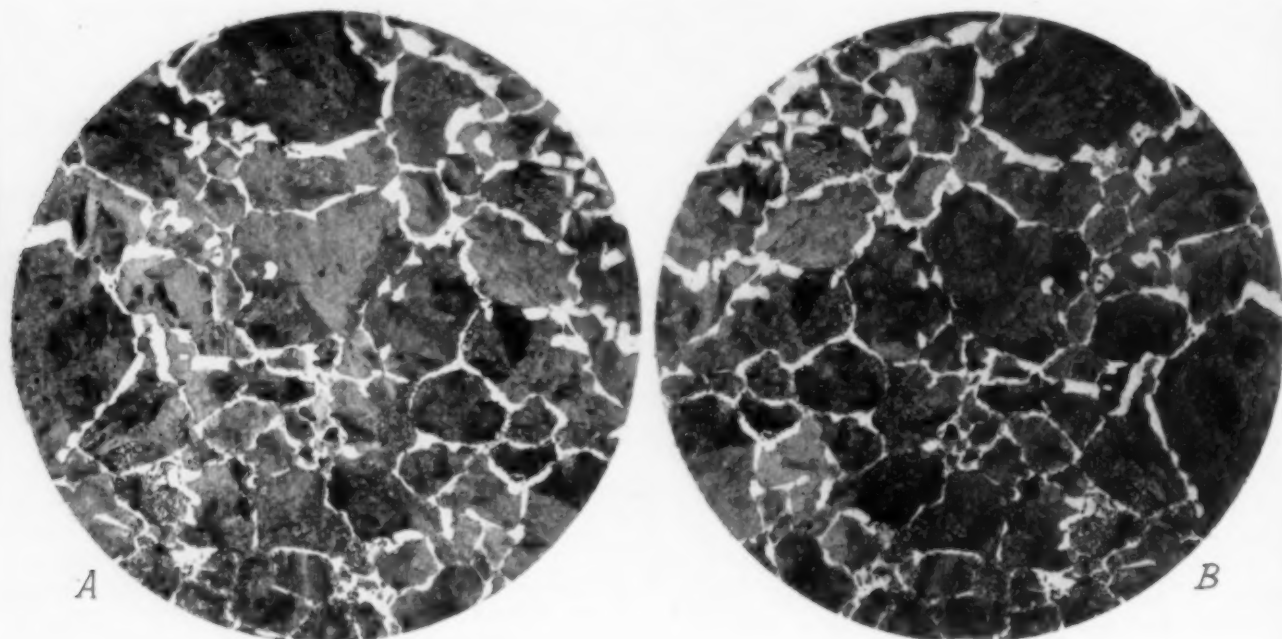


Fig. 1 — Magnification X 100, "A"— Inverted; "B"— Upright

were of superior quality, for in microscopy the quality of the image is the most important consideration. But the fact is that the quality of the image is influenced, not by mechanical factors such as upright or inverted construction, but primarily by the quality of the objectives and eye-pieces, by the precision of alignment of the various parts of the instrument, and by the system of illumination. With a properly built upright microscope equipped with a good vertical illuminator, results are obtainable, both in visual examination and photomicrography, which approximate those of the finest inverted microscope.

In the accompanying pairs of photomicrographs, Fig. 1 to 4, an attempt is made to show how close this approximation is. Each pair represents the same field photographed in "A" with an

inverted instrument (Zeiss Neophot) and in "B" with an upright instrument (Bausch and Lomb Model CM). It should be noted that the image produced by the latter is inverted with respect to that produced by the former, that is, the pair of pictures are mirror images of each other.

In comparing the results obtained with these instruments, one costing many times more than the other, no disparagement of the Zeiss Neophot is intended. On the contrary, it was selected as the standard in this comparison because it is known to embody the highest optical and mechanical excellence. Nevertheless, with a comparatively inexpensive microscope, well made, yet of the simplest practicable construction, it is quite possible to make photomicrographs which are comparable in quality with those made with one of the

Fig. 2 — Magnification X 500, "A"— Inverted; "B"— Upright (Some of the Faint Figuration in Light Areas of "B" Has Been Lost in Half-Tone Engraving)



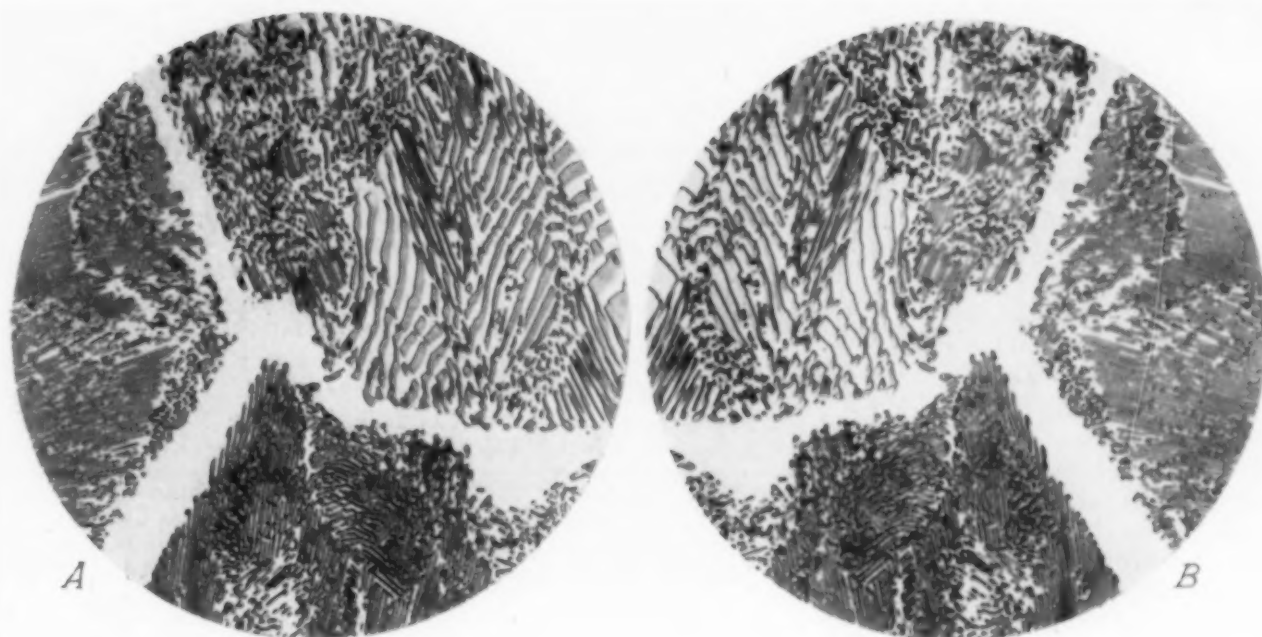


Fig. 3 — Magnification X 1000, "A"— Inverted; "B"— Upright (Some Very Light Shadings Along Lamellar Edges in NW Quadrant Lost in Half-Tone Engraving)

finest and most expensive microscopes ever built.

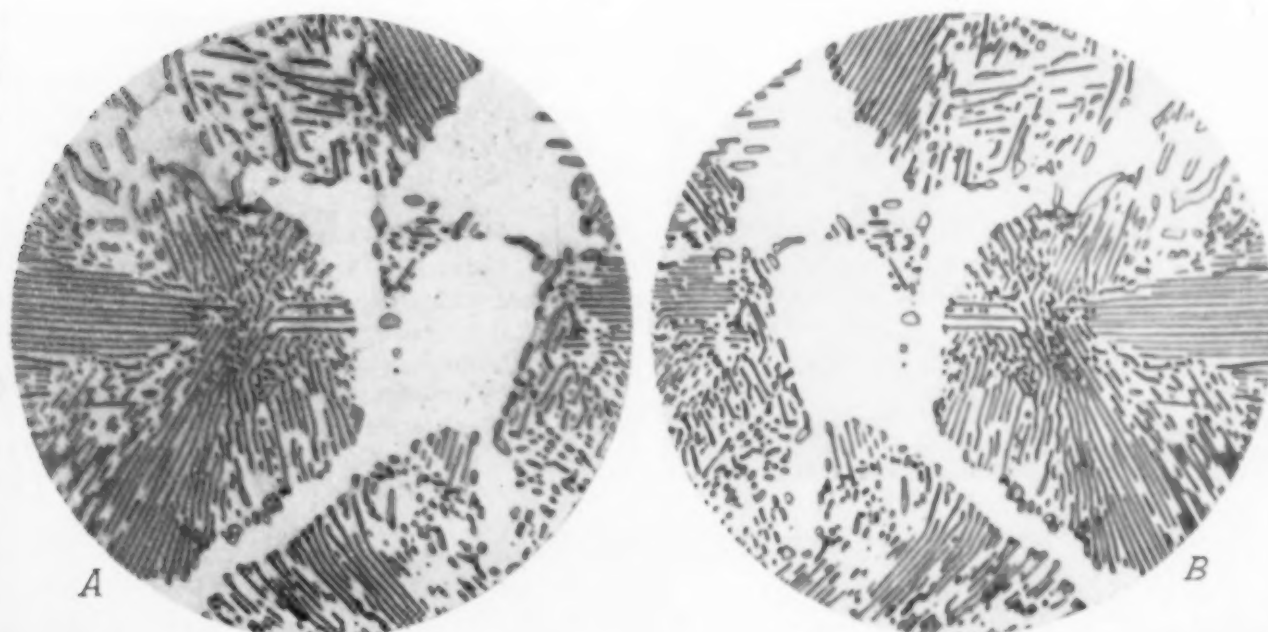
There are certain facts that must be borne in mind to interpret correctly these photomicrographs.* Every precaution was taken to obtain the best possible image with each instrument. Since there was available for the inverted instrument a set of apochromatic objectives, these were used in combination with a light filter of maximum transmission in the blue-violet in order to obtain the best possible resolution. The lenses available for the upright instrument are achromatic except the 2.75-mm. oil immersion, which is a fluorite or

semi-apochromatic objective; these lenses require a yellow-green filter for optimum performance, and since such a filter is supplied by the manufacturer, it was used. This difference in light filters gives a definite advantage in resolving power to the pictures made with the inverted type, and also alters considerably the appearance of the structure.

The photomicrographs made with the inverted type were taken on Wratten metallographic plates (which, in the writer's opinion, are best for the purpose), while those made with the upright instrument had to be taken on a much faster, less contrasty emulsion, owing to a much lower intensity of illumination available. These differences in light filters and photographic emulsions are solely responsible for such difference in appearance

*EDITOR'S NOTE — Allowance should be made in advance for the inevitable loss in clarity and contrast even in the best half-tone engraving of 160-screen, and in printing on such paper as is available to publishers these days.

Fig. 4 — Magnification X 2000, "A"— Inverted; "B"— Upright



between "A" and "B" as is exhibited, particularly in Fig. 2 and, to a lesser extent, in Fig. 3. In neither case was the specimen re-etched between the two pictures.

The engraving at the beginning of this article shows the arrangement used for making the "B" photomicrographs. It consists of a CM microscope and a Leitz camera that happened to be available. These were set up on a home-made device for damping vibrations, consisting of two boards separated by several coil springs of the right stiffness to "float" the microscope and camera.

Note in particular that the illuminating unit with which the microscope is equipped for visual examination is also used for photomicrography. This illuminating unit consists of a 25-candle power bulb in a totally enclosed lamp housing; a transformer is used to supply 8-volt current from a 110-volt source.

Fig. 5 — Small Press Used for Mounting Specimen on Plasticine so It Will Lie Perpendicular to Optical Axis of Microscope

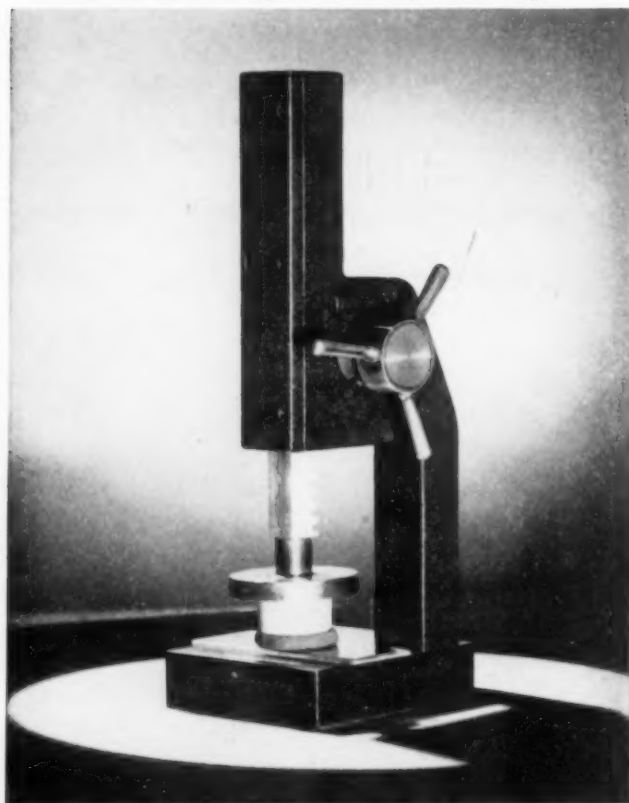



Table of Photographic Data

FIG- URE	MAGNI- FICATION	MICROSCOPE	OBJECTIVE	FILTER	EXPOSURE
1A	X100	Inverted	11X, N.A. 20, Achromat	Green	—
1B	X110	Upright	24-mm., N.A. 20, Achromat	Green	3 sec.
2A	X500	Inverted	30X, N.A. 65, Apochromat	Blue	—
2B	X500	Upright	5.5-mm., N.A. 65, Achromat	Green	15 sec.
3A	X1000	Inverted	60X, N.A. 95, Apochromat	Blue	—
3B	X1000	Upright	4-mm., N.A. 85, Achromat	Green	20 sec.
4A	X2000	Inverted	90X, N.A. 1.4, Apochromat	Blue	—
4B	X2000	Upright	2.75-mm., N.A. 1.25, Fluorite	Green	35 sec.

Development Data — All "A" pictures were made in Eastman Kodak Wratten metallographic plates and developed in D19 for 3½ min. at 68° F.

All "B" pictures were made on Eastman Kodak Super Panchro Press, Type B, and developed in full strength Eastman Kodak Dectol, 4½ min. at 68° F.


Photomicrography at both low and high magnification with only a 25-candle power bulb is possible because

1. This light intensity is sufficient to permit focusing with a focusing magnifier on a plain glass screen — or (better yet) in mid-air, by the method described by the author in "Metallographic Technique for Steel", an  publication.

2. There is enough light to record the image in a reasonably short exposure on the fast photographic emulsions available today.

A suitable film is one that combines high speed and high developable contrast. It is obvious that any photographic emulsion can be used if one is willing to expose it long enough, but the use of a slow emulsion and long exposure is inadvisable, particularly in industrial districts, because the negative is likely to lack critical sharpness owing to vibration of the instrument during exposure. While a short exposure is highly desirable, it is often necessary to resort to a photographic emulsion of medium speed in order to obtain sufficient contrast in the image. According to our experience the fastest available emulsion (Eastman Kodak Super Panchro Press, Sports Type) is not the best for metallographic purposes because it lacks sufficient contrast even in a strong developer (undiluted D19 or Dectol).

Better results are obtained with Super Panchro Press, Type B, developed in undiluted Dectol; this was used in making the illustrations for this paper. Pertinent details are given in the table at the head of this column.

One slight disadvantage of the upright microscope is that in order to make the specimen lie perpendicular to the optical axis of the instrument it is often necessary to mount it in a soft modeling material, such as plasticine. This is very easily done with the small press shown in Fig. 5, or with any similar device purchased from suppliers of metallographic equipment. 

Hard Carbides

The German Cemented Carbide Industry in 1945*

By Gregory Comstock

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EARLY in the investigation made for the U. S. War Production Board into the cemented carbide industry in Germany and Austria it became apparent that the hard cutting tools were awarded extreme importance both by the German high command and the Nazi government agencies. High priorities were issued. Research and development were urgently demanded. Operations were pressed until the very last, plants being repeatedly moved from bombed areas. Tools were standardized and apportioned to those applications where they would be most effective.

Early in the war the control of the industry was vested in the *Hartmetallezentrale* which allocated raw materials, controlled manufacture and allocated product from five regional stocks. In the first stage of the control the operations of producers and customers and their mutual relations were frozen at about their pre-war status. Later, in the second stage of industrial control, the sizes and shapes were standardized, trade names such as Krupp's *Widia* were dropped and *Deutsches Hartmetall* substituted, customers were allocated to definite producers, and small plants with obsolete equipment closed. Finally a tighter central control agency called *Bewirtschaftungsstelle Hartmetalle* was established, the demands and uses of the individual customers were investigated, idle stocks moved to active plants, production geared to overall demand, and an educational program was directed toward a more efficient use of the tools in the machine shops.

The principal plant for the production of tungsten powder was at Wuppertal and was owned by Krupp. The ten plants making carbide tools and their capacity in kilograms per month were as listed at the top of the next column.

Standardization to eliminate variations in size and composition (grades) was pressed vigorously as the war proceeded. No less than 350 tips for cutting tools were available under the 1937 "standards"; there were 41 in 1940. Final revision of the

German Plants Making Carbides

LOCATION	OWNER	MONTHLY CAPACITY
Langenbielau	Krupp	20,000 kg.
Essen	Krupp	15,000
Wuppertal	Krupp	12,000
Wernshausen	Krupp	10,000
Bremen	Krupp	8,000
Reutte	Deutsche Edelstahlwerke	4,000
Whithofen	Gebrüder-Bohlers	3,500
Langenburg	Krupp	3,000
Krefeld	Deutsche Edelstahlwerke	3,000
Prague	Poldihütte	1,000

specifications for standard tips was enforced through the national standard DIN-4966, reproduced as Fig. 1 and 2 on the following pages. At the end of the war the director of the central control estimated that 85% of all metal machining was done with these standardized tips.

Standardized Compositions or Grades

Ten standard grades of hard cemented carbide were selected to cover the whole range of hard metal application. While they were referred to as the "war grades", they were, of course, actually materials resulting from all of the research, development, production, and application experience which the industry had accumulated since *Widia* was introduced in 1926. Six of these grades were most widely applied to machine tooling and were supplied in the form of standard tips, namely, S1, S2, S3, G1, G2 and H1. A seventh grade, F1, was also supplied for certain specific tools. Requests for non-standard tips or for special compositions were discouraged and required a special permit. These grades and two non-standard special grades F2 and G3 have the composition and physical properties shown in Table I after the heat treatment specified. Table II contains German data

*From a report to the Technical Industrial Intelligence Committee of the Foreign Economic Administration, U. S. Government.

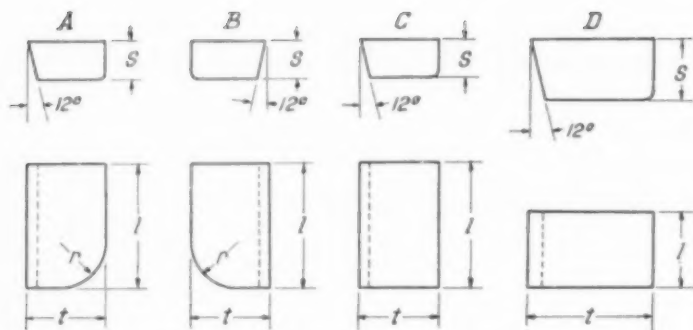


Fig. 1—German Standard Tip Sizes for Medium and Heavy Cutting (December 1943)

l	Form A,B,C			Form D	
	t	s	r	t	s
3				7	2
4				8	3
5				10	4
6				12	5
8				14	6
10				17	8
12				20	10
20	12	6	8		
25	14	7	8		
32	16	8	10		
40	18	10	10		
50	20	12	12		

Measurements, Mm.

thought to be representative of the actual composition of these grades as manufactured under war-time conditions. Absence of hardness data in Table I is characteristic of German practice — no emphasis is placed on their hardness as indicated by resistance to permanent deformation. Grades G1 and H1 are of the same composition but of different final particle size.

Grade G1 represents the original Widia introduced by Krupp in 1926. Production that year was 1074 kg. By 1933, when S1 was introduced, production was 11,904 kg. and steadily increased to 1942 (56,303 kg.). In common with the doubled German production of all carbides in the next

year, the production of all G grades was 99,423 kg.

Grade S1, introduced in 1933, rapidly increased in popularity. In 1943, 210,354 kg. was produced, 41% of the total production of all carbides for all German industry.

Production during 1943 of the various grades was as follows:

S1	210,354 kg.
S2	81,149
S3	80,596
G grades	99,423 (total)
H1	35,668
H2	819
F1	1,177
Total	509,186 kg.

Uses of the Various Grades

Grades S1, S2, S3, F1 and F2 are primarily designed for steel cutting. The G and H grades are for cast iron, non-ferrous metals and alloys, and non-metallic materials. S1, S2 and S3 are of progressively increasing strength and decreasing hardness, as are the series G1, G2 and G3. Grades H1 and H2 are carefully developed special grades. H1 is of the same nominal and almost identical actual composition as G1 and has the same bending strength but is somewhat harder. It is sintered for a shorter time and has a finer ultimate grain size. Grade H2 contains small quantities of vanadium and tantalum carbides; it is the hardest standard grade produced and is employed in the machining of extremely hard materials.

Consideration of the composition of these

Table I—Physical Properties of German Carbides for Cutting Tools

GRADE	NOMINAL COMPOSITION			SINTER-ING TEM-PERATURE	SINTERING TIME FOR TIPS OF THICKNESS		BENDING STRENGTH	COEFFICIENT OF ELASTICITY	THERMAL DATA			SPECIFIC ELEC-TRICAL RESIST-ANCE
	WC	TiC	Co		2 Mm.	15 Mm.			EXPAN-SION	CONDCU-TIVITY	SPECIFIC HEAT	
S1	78	16	6	1600° C.	20 min.	100 min.	175,000 psi.	54,000 (a)	6 (b)	0.09 (c)	0.06	0.43
S2	78	14	8	1550	20	100	200,000		6.2	0.08		0.44
S3	88	5	7	1500	20	100	210,000	59,000	5.5	0.15	0.05	0.25
G1	94	—	6	1420	20	100	225,000	62,000	5	0.19	0.05	0.2
G2	89	—	11	1400	20	100	255,000	58,000	5.5	0.16	0.05	0.18
G3	85	—	15	1380	17	60	290,000					
H1	94	—	6	1420	17	60	225,000	64,000	5	0.19	0.05	0.21
H2	91.5	(d)	7	1500	66	220	165,000		5			0.25
F1	69	25	6	1550	66	220	155,000	52,000	7	0.05		0.65
F2	34.5	60	5.5	1700	66	200	115,000					0.77

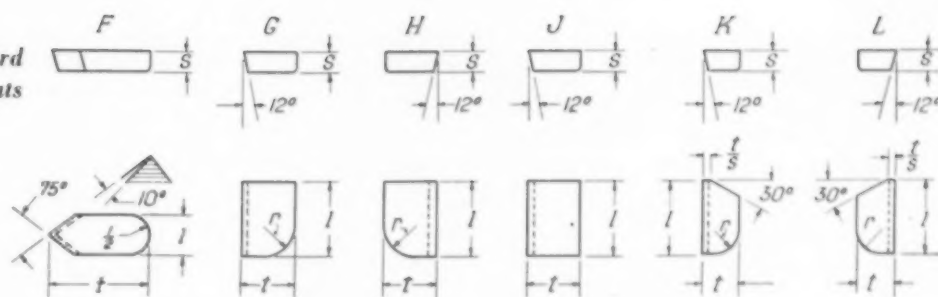
(a) In kilograms per square millimeter. (1kg/mm² = 1422 psi.)

(b) In 10⁻⁶ cm. per centimeter per °C.

(c) In calories per second per °C.

(d) Plus 1% TaC and 0.5% VC.

Fig. 2—German Standard
Tip Sizes for Light Cuts



materials, their reported physical characteristics and their recommended applications would seem to indicate an extremely well chosen group of hard cemented carbides for wide application in general industry. The use of tantalum or columbium as carbide additives to hard metal has always been discouraged in Germany—possibly because of their scarcity. German war research reports secured during the investigation showed a marked tendency toward the use of columbium in small but significant percentages.

In German machining practice, grades of hard carbide are recommended on the basis of the material to be cut—that is, ferrous or non-ferrous, non-metallic and so on; the amount of material to be removed as measured by the depth of cut at high, medium or low speeds; the strength or cutting characteristics of the materials to be machined; the type of operation, whether turning, milling, or boring; and special considerations such as finish.

On such a basis grade S1 is recommended for general steel cutting, although comparatively light cuts at high speed are specified and applications are limited to machine tools capable of taking full advantage of carbide cutting efficiency. As shown in the table of production, this grade is the most generally employed. Grade S2 is for heavier steel cutting, with permissible increases in depth of cut up to 130% of those recommended for S1. S3 is recommended for still heavier cuts, for intermittent machining operations, and for use in old machine tools.

Grade G1 is the original Schroeter composition

l	Form F		Form G, H, J			Form K, L		
	t	s	t	s	r	t	s	r
4	12	2						
5	14	25						
6	16	3	4	2	2			
8	18	4	5	2	3	4	2	3
10	20	5	6	25	4	5	25	3
12	25	6	8	3	5	6	3	4
16			10	4	6	8	4	5
20						10	5	6

Measurements, Mm.

refined by production experience and research. It is recommended for the machining of cast iron, copper, the light metals and a variety of other materials. It is used in quantities second only to grade S1. Grades G2 and G3 are recommended for progressively heavier cuts of the G1 type, and for operations involving increasing resistance to shock or impact.

Type F1 was developed for such special uses as the boring of aircraft cylinders or other similar applications where light cuts of long duration and extremely fine tolerances are involved which permit of little or no tool end wear. Another example is for the close tolerance machining of connecting rods, 500 to 700 per grind.

H grades are for machining alloys either naturally hard or hardened by heat treatment.

For surfacing or shaping operations, S grades are recommended for steel, and G grades for iron and a variety of other crisp cutting materials.

Table II—Representative Composition, Weight and Hardness of German Carbides

GRADE	CARBON		W	Co	Ti	Fe	Cr	Ni	Nb	SPECIFIC GRAVITY	ROCKWELL HARDNESS
	FIXED	FREE									
S1	7.57	0.21	73.33	5.48	12.76	0.31	0.03	0.10	0.26	11.15	A-91.0
S2	7.30	0.22	73.06	7.64	11.13	0.28	0.05	0.11	0.29	11.25	A-90.5
S3	6.17	0.16	82.55	6.63	3.77	0.25	0.05	0.09	0.15	13.30	A-90.0
G1	5.90	0.15	87.75	5.68	—	0.34	0.09	0.10	0.06	14.70	A-90.0
G2	5.65	0.18	83.22	10.46	—	0.38	0.05	0.12	0.03	14.20	A-88.5
G3	5.50	0.32	79.32	14.46	—	0.40	0.06	0.10	0.03	13.70	A-87.0
H1	5.83	0.12	87.82	5.66	—	0.30	0.05	0.11	0.03	14.75	A-91.0
H2*	5.83	0.16	85.14	6.80	—	0.28	0.06	0.11	0.03	14.40	A-91.5
F1	8.10	0.06	66.86	5.48	18.30	0.40	0.13	0.15	0.42	9.90	A-91.5
F2	12.8	0.05	32.40	5.25	46.60	0.71	0.14	0.10	1.14	6.8	A-92.5

*Additional elements: 0.77% tantalum, 0.5% vanadium, 0.20% niobium.

How these grades, prepared in the German method, would perform when applied to the various conditions prevailing in American metal working industries can only be ascertained by laboratory and shop trials. While it is believed that our own products are in no way inferior, but on the contrary are made from more carefully prepared and superior raw materials by methods better calculated to produce uniformity and efficient performance, a direct comparison should doubtless be made. Stocks of all of the standard and many of the special German grades and tips have been secured and are available for examination.

Before the war, German tool and machine practices differed quite materially from ours. The cutting tools were larger and were held more rigidly than ours. The carbide tips were larger. More skilled hand operations were used than in American mass production. Hard metal was more generally employed and was possibly treated with more care than we accorded it at first.

This investigation indicated that these differences were by no means as great at the end of the war as they were before. An effort had obviously been made to duplicate or even to improve upon our machine and tooling practice. The opportunity presented by the war for a general overhauling and standardization of German tool practice was unique and apparently advantage was taken of it.

Improvements in Carbide Manufacture

Notable improvements in manufacture during the last 12 years, as noted by technical executives of the *Hartmetallezentrale*, are:

"The mixture of tungsten and carbon was originally tamped into carbon boats previous to carburization. Since 1939 this mixture has been pressed into briquettes with sufficient green strength to be handled, and inserted in this compressed form into graphite containers. This method saves labor, affords better carburizing, and increases production per furnace.

"Before 1931 carburizing was accomplished in gas fired furnaces. Electric furnaces were employed after that date. These furnaces are of the graphite tube resistance type. The length of the carburizing furnaces has been increased from the original 36 in. to 6½ ft. within the last few years. This increase in the length of the uniformly heated high temperature zone permits a higher stoking rate and the output per furnace has been tripled.

"In order to increase the output of the Essen works, a milling machine of 23.5 cu.ft. capacity was put into operation, replacing those of 8-liter capacity (about 1 cu.ft.) used up to 1940. The charge of carbide plus binder is now 250 kg. (560 lb.).

"Another marked improvement was the introduction in 1940 of the oscillating or vibrating mill for the grinding of graphite or sugar carbon, as well as the grinding of carbide plus binder. Milling time in this type of mill is only one-sixth of that required for the

standard rotating ball mill. Graphite or sugar carbon is pulverized in these mills with porcelain balls. Steel balls are used for blending tungsten and carbon in this mill, and hot-pressed carbide balls are employed for grinding tungsten carbide plus metal binder.

"In 1941 a new system was installed for drying the wet ground carbide plus binder mixtures. This consists of applying a low vacuum to the mills when they are immersed in a water bath heated to 80° C. This removes practically all water in the mix in a relatively short time and does not involve the use of hydrogen.

"Previously the mixed powders, ready for pressing, were moistened in small quantities with a sprayer and then mixed by hand. After 1938 this operation was performed in a mixing machine of 20-lb. capacity. As a moistening agent, Krupp has recently used acetone, glycol or methyl alcohol as well as the old solution of 70 g. camphor to 1 l. benzene (0.035 cc. of solution per kilogram of pressing mixture). Glycol was particularly successful.

"The pressure required for titanium grades is 50 to 100 kg. per sq.cm. (700 to 1400 psi.); for G grades, 1200 to 1700 psi. and for H1 and H2 1400 to 1700 psi. Pressure has to be higher for H1 and H2 because the height of these mixtures as poured into molds is greater than that of the G grades and, therefore, higher pressure becomes necessary if the compressed product is to have the same weight-size ratio.

"With the advent of standardized tips, improvements were possible in their pressing. The Germans press one tip at a time in hand-powered presses, which is much faster than might be expected. In one of the plants 200,000 tips per month were produced from prepared powders with approximately 30 employees engaged in all operations.

"1940 saw a major change in the methods of producing tungsten-titanium carbide compositions (grades S1 and S2). Originally tungsten carbide, titanium carbide and cobalt or nickel powders were wet ground, dried, lubricated and subsequently pressed and sintered. The method employed at Reutte of heating the mixed carburized powders to high temperature produced a more homogeneous mixture; a possible improvement in the control of crystal growth was also noted. In the manufacture of grades S1 and S2, mixtures of tungsten carbide, titanic acid and carbon are heated to 1700° C. as a substitute for the Reutte process. (The temperature required for most efficient formation of titanium carbide from oxide or powder and carbon, in the German practice, is *very* high—in the neighborhood of 2300° C.) The advantages of this innovation are the elimination of previous milling operations applied to the individual carbides; the use of lower temperatures which greatly prolongs the life of the furnace; increased homogeneity and control of ultimate particle size, and increased production per unit of milling and furnace equipment.

"To increase the differences in characteristics between them and thereby permit a broader spread of application, the titanium carbide content of S2 was lowered by 2% and the cobalt content of grade S3 was increased one unit to 7%.

"Grade H2 was developed in 1938 by Krupp for the machining of chilled castings over 90 scleroscope hard. In the same year, grade F1 was produced for the fast finishing of steel; during the war, grade F2 was developed for a further increase in cutting speed.

"The possibility that the stocks of tungsten avail-

able for hard cemented carbide might be exhausted should the war be indefinitely prolonged induced concentrated research at the beginning of the war for a tungsten free hard carbide cutting material.* The experiments were successful and culminated in a titanium-vanadium substitute for S1. Tool tips of this material have been used for some time in mass production under these conditions as grade S1 tips. This grade is called V814 and its composition is 45% titanium carbide, 45% vanadium carbide and 10% nickel (or 7% Ni plus 3% Co). It is generally hot pressed, although it can be made by the cold press vacuum sintering method.†

Grade V814 was still under investigation and large numbers of tips have been secured for actual test in the United States.†

Hot Pressing of Powder

Seven years of consistently good engineering have brought the hot press to a high state of perfection in Germany, and it became an efficient production implement in the carbide industry. The advantages of the hot press for producing quickly and inexpensively very large objects of hard cemented carbide or of a limited number of pieces of intricate cross-section have been recognized in this country for a long time. These assets have been carefully retained in the German practice. One of the chief difficulties was its excessive use of graphite dies and plungers. The German engineers have by-passed this by pressing thin walled cylinders or other tube forms, broached from graphite, into heavier graphite mold containers. These liners may then be replaced with a minimum discard of reclaimable graphite. Plungers are re-machined to original contours by form cutters with little loss of either time or material. In order to minimize plunger movement during pressing, the powders are pressed into the temporarily reinforced composite graphite molds under heavy hydraulic pressure previous to hot pressing.

The German hot press is of the graphite resistance type—the spring-clamped mold being the resistor, with a separate mechanical or hydraulic system available for applying top and bottom pressure on plungers. A most ingenious series of auxiliary machines has been designed for the mass production of mold, plunger and separator forms, and for grinding and finishing the product,

*This shortage was probably hastened by the use of tungsten carbide cores for armor piercing projectiles—33 tons per month as a maximum.

†Harry Crump, another American observer, notes another German substitute, an aluminum carbide, although extremely hard, gave rather dismal results. In fact, the Germans themselves admitted that tools made from aluminum carbide were “not too good”. This *ersatz* carbide could be used effectively only for light cuts on non-ferrous metals such as brass.

resulting in a system of hot pressing rather than improving the hot press as a unit device.

One of the difficulties associated with the simultaneous application of great heat and even relatively low pressure has been the loss of the molten binder by extrusion. The Germans have overcome this by controlling the final volume of carefully weighed pre-pressed charges having a constant density. A consistent and controllable binder loss on the order of 2% is mentioned for hard carbide compositions having originally as much as 13% of the auxiliary metal.

The production cycle of this system is calculated to produce a finished hot pressed mold charge in from 3 to 7 min. for pieces weighing from 50 to 1000 g. (2 oz. to 1 lb.). Larger objects, of course, require a longer time. As many as 19 12-oz. pieces have been manufactured in one mold.

While the German hard carbide industry has apparently nothing comparable to the new American cold extrusion process, they have made a most notable improvement on hot pressing apparatus and technique.


The actual physical condition of the industry at the time of the surrender is difficult to evaluate. Many investigators returning from Germany have stated that the particular industry they have inspected could be put back into operation in a relatively short time. Bombed plants can be cleaned up, new buildings erected and the damaged and undamaged equipment reassembled for renewed production. However, when one considers the delays we encountered in war-time America by failure to secure promptly a valve which could previously be obtained from local stocks, one wonders what delays will occur in Germany. The German hard carbide industry could be put back into full production, probably in a few months' time, if the other industries were functioning on a pre-war basis.

The ten manufacturing plants are in every possible condition from those which are absolutely untouched to those so badly damaged that almost every piece of equipment must either be discarded or given major repairs. In this industry, as in many others, it has been found—surprisingly enough—that when the walls and roof of a factory have been bombed flat and everything has fallen down on the equipment, the heavier apparatus itself can survive with relatively little damage. A German rolling mill superintendent, showing a party of Americans his prize mill and necessarily peering at it through a mass of fallen girders and brickwork, said, “This mill is entirely operable—it is only slightly disarranged”.

A similar remark might be as fittingly applied to the German hard cemented carbide industry. ●

German Toolsteel and Special Steel Industry

By James P. Gill

Scientific Consultant, Technical Industries Intelligence Committee, The Joint Chiefs of Staff
(Past President,  , Executive Vice-President, Vanadium-Alloys Steel Co.)

FIVE companies marketed practically all of the toolsteel and special steels that were used in Germany. ("Special steels" include heat and corrosion resisting steels, magnet and electrical steels, and welding rod, as well as engineering steels corresponding to the American S.A.E. steels.) Three of these companies were strictly German; one was Czechoslovakian and the fifth had its home offices and one plant in Austria and another plant in Germany. The three German companies were the Deutsche Edelstahlwerke at Krefeld, Krupp located at Essen, and Rochlingstahl at Wetzlar. The Czech company was the Poldihütte having its main plant at Kladno. The Austrian company was Bohlers Werkzeug Stähle with the main plant at Kopfenberg, Austria, and another plant at Düsseldorf, Germany. Apparently Bohlers enjoyed the largest sale of special steels, closely followed by Deutsche Edelstahlwerke.

The five companies maintained branch warehouses in all of the large industrial areas in Germany, the number of these warehouses being between about eight to twelve for each company. The warehouse stocks were quite complete as to sizes and grades and the aggregate amount is of large proportion. Contrary to the American custom, the mills did not carry large stocks at the places of manufacture unless the location was in a highly industrial area such as Krupp at Essen.

A striking similarity apparently existed in the methods of manufacture in all five companies. (This statement is based on the study of the methods of manufacture at Edelstahlwerke and Rochlingstahl.) All made their product in the form of rolled and forged bars, cold drawn and ground bars, wire, plate and sheet. Practically all of the steel was melted in electric furnaces yet each of the companies had some openhearth capacity in which carbon and low alloyed steels might be manufactured.

For example, Rochlingstahl was equipped with one 30-ton openhearth furnace using coke oven gas and three electric furnaces of 20, 10 and 6-ton capacity. Edelstahlwerke had nine electric arc furnaces between 6 and 30-ton capacity, two induction furnaces of some 5-ton capacity, and three basic openhearth of 35-ton capacity.

Melting practice was quite similar to that used in America, highly alloyed steels such as high speed steel being dead melted, while carbon and special steels (such as the ball bearing type) boiled by the addition of approximately 1000 lb. of ore to a 10-ton charge. Slags were made by mixing fluorspar, carbon and lime; usually two slags were used although three slags have been tried for some steels. Usually aluminum was used for deoxidation, the average aluminum addition being 4 lb. for a 10-ton heat.

As to ingot practice, both Edelstahlwerke and Rochlingstahl cast tapered square ingots and tapered round ingots, the latter sometimes termed "conical" ingots. The molds are open at both ends and set on a cast iron flat stool about 6 in. thick. The ingot size varied greatly, from as small as 300 lb. to as large as 8 tons, it apparently being the intent to cast as small an ingot as consistent with the size of the bar to be manufactured. The molds were given a wash of hot tar. A hot top was used which consisted of a large cast iron ring into which was set a tapered clay container, either square or round in accordance with the shape of the ingot. Mud was rammed between the clay container and the cast iron ring. The whole top assembly was heated to about 1100° F. and placed on the mold before casting. The hot top generally contained about 10% of the ingot volume.

The standard square ingot at Rochlingstahl weighed 1600 lb. with cross-section of 11¾ in. square at the top and 9½ in. at the bottom and a length of 4 ft. The molds were usually round on

**Table I — Analysis of Nitriding Steels
Made by Poldihütte**

BRAND	C	MN	SI	CR	MO	V	AL
L-AL 12	0.33	0.45	0.25	1.80	0.18	(a)	1.10
L-AL 14	0.44	0.55	0.25	1.50	0.23		0.95
L-AL 16	0.35	0.75	0.30	1.65			1.10
L-AL 30	0.32	0.70	0.30	1.10	0.18		1.15
L-NIT 2	0.30	0.60	0.40	2.50	0.25	0.25	
L-NIT 4	0.27	0.60	0.40	2.50		0.30	

(a) 1% nickel

the outside and the radius of the inside corner was quite large, being about 3 in. A mold for casting a 1600-lb. ingot weighed 2700 lb.

The round ingots were usually of three weights — 450, 900 or 1350 lb. — with the major portion of the steel cast in 900-lb. ingots. This ingot had a top diameter of 11¾ in., a bottom diameter of 9¼ in. with an ingot length of 31½ in., not including the hot top. The hot top for this ingot was approximately 9½ in. at the bottom, 6¼ in. at the top and 11¾ in. long.

All ingots regardless of composition were annealed immediately after casting, the ingots apparently being kept at a comparatively hot temperature until they could be placed in the annealing furnaces. The hot beds were heated. After annealing, practically all of the ingots were rough turned, to a depth varying somewhat with the composition of the steel. Turning equipment was available for both round and square ingots, the square ingots being turned on lathes of the profile type whereby the tool follows the contour of the ingot. It was possible to turn 12 of the 2700-lb. soft steel ingots in 8 hr. and five ingots of hard steel such as high speed.

All highly alloyed steels and nearly all types of toolsteels, with the exception of straight carbon steels, were hammered, while steels of the S.A.E. type were pressed. At Rochlingstahl there was available one 1800-ton press, one hammer of 6700-lb., three hammers of 3300-lb., two hammers of 2200-lb. capacity, and a number of smaller ones. All heating was by the use of coke oven gas. Nothing unusual existed in the forging or rolling practices.

The largest size of high speed steel rolled at Rochlingstahl was approximately 1⅞ in. diameter; at Edelstahlwerke the largest size was approximately 2 in. The larger sizes were hammer finished, and the largest hammer finish in high speed steel was generally about 5 in. in diameter. Sizes above this were made of upset forgings. The largest size of carbon and low alloy toolsteel that was rolled at either plant was usually in the vicinity of 6 in., with the larger sizes hammer

finished. The smallest hot rolled sizes were 0.210 in., and these small rods were usually coiled for drawing in the wire mill. The sheet mill at Rochlingstahl could roll sheets up to 4 ft. wide and 10 ft. long.

The cold drawn division of Rochlingstahl appeared comparatively small even though the management stated that the mill had a capacity of approximately 200 tons per month. It contained only four centerless grinders for wire or bars within the limits of 0.080 and 1.0 in. The mill contained a large number of benches for wire drawing, most of them having drums individually driven. The Edelstahlwerke contained a much larger wire drawing department even though the equipment was quite similar.

The Rochlingstahl works contained no tube mill while Edelstahlwerke had one of large size and capable of producing tubes as large as 8 in. O.D. Apparently much of the tubing produced by the latter was for bearing races.

**Table II — Edelstahlwerke Steels for Moderate
Heat and Hydrogen**

BRAND	C	SI	MN	CR	MO	V	W
HC 5	0.10	0.35	0.40	2.60			
HC 8	0.25	0.35	0.40	2.60			
HC 9	0.20	0.35	0.40	3.10	0.25	0.50	
MC III V	0.20	0.30	0.40	2.60	0.40	0.80	0.40
Steels for Hydrogen Resistance							
CV 30	0.30	0.30	0.20	1.00	0.20		
CV 60	0.30	0.30	0.40	1.35	0.55		
CV 70	0.15	0.30	0.40	1.00	0.30	0.25	
CV 110	0.30	0.30	0.40	1.40	1.10		
CV 120	0.30	0.30	0.40	1.40	0.55	0.40	

Annealing Practice

The Rochlingstahl works contained a battery of 15 annealing furnaces, the largest of which was capable of holding about 20 tons. All toolsteels and high speed steels were packed and sealed in pipes; no packing compound was used, and the ends of the pipes were merely "mudded" in. The pipes were quite large, being approximately 14 in. in diameter and were made of low carbon steel. Nearly all of the annealing furnaces were of the car type and all were gas fired. The pipes were supported in the furnace on cast iron cradles lifting them about 6 in. from the furnace bottom. Only a few pipes were charged in each furnace, the number usually being from three to six. General practice seemed to be to heat the steel to the desired annealing temperature after which it was held for about 8 hr. and then cooled about 24 hr. with the furnace.

Toolsteels Manufactured

All of the five companies mentioned manufactured materials of a similar nature, consisting of high speed alloy and carbon toolsteels, special steels such as magnet steels and valve steels, heat and corrosion resisting steels, and structural alloy steels of the S.A.E. type.

A comparison of the compositions manufactured in 1939 with those of 1945 reveals some changes as a result of lack of alloying metals. A direct comparison exists in the list of toolsteels as made by Rochling,* one list showing the compositions manufactured in 1939 and the other showing those manufactured in the fall and winter of 1944. There was a decided preference in 1939 for high speed steels containing about 13% tungsten, 4% chromium and high vanadium (from 1½ to as high as 5%). The carbon was likewise proportionately increased with the vanadium content, in one instance being as high as 1.50% and a cobalt content of 4.75%. Many of the high speed steels contained cobalt from as low as 2 to as high as 15%. As a result of the lack of alloying metals a high speed steel was developed containing from 0.90 to 1.00% carbon, about 4% chromium and tungsten, molybdenum, and vanadium each within the limits from 2 to 3%.

All of the men interviewed who *manufactured* this steel were very enthusiastic regarding its performance. Dr. Houdremont, for example, stated that it averaged about 20% better than a standard 18% tungsten high speed steel for general applications. All manufacturers did admit, however, that it was very sensitive to grain growth and must be heat treated within narrow temperature limits to obtain good performance. The usual recommended quenching temperature was 2265° F., tempering at 1015° F. (double tempering being standard practice with this steel as with all other high speed steels). It is interesting to note, however, that Krupp manufactured this steel with an addition of 0.05 to 0.10% titanium. In questioning other manufacturers of this steel as to whether they used any alloying elements or deoxidizers other than those already stated they invariably said "No", and it appeared that Krupp only used titanium. Dr. Houdremont stated definitely that if

*The original report, obtainable for a nominal sum from the Publication Board, Department of Commerce, Washington, contains extensive tabulations of the analyses made by the German plants.

titanium were omitted the steel would be more susceptible to grain growth.

A number of *tool makers* were visited and in discussing the performance of this special high speed steel (which Dr. Houdremont termed the "Holy Trinity") they invariably stated that they considered it definitely inferior to the standard types. Hans Kiehm, director of Franz-Mossmann, manufacturer of twist drills, was quite emphatic in his statements regarding its inferiority.

Molybdenum high speed steels did not seem to find much favor among either the German manufacturers or users even though several of the companies had obtained licenses to manufacture high speed steel of the "Mo-Max" type. Little or no molybdenum was produced in Germany or by its satellites, which may explain its small use.

Compositions of toolsteels for hot work appear to follow rather consistently the American practice, although a much wider range of compositions was available for this purpose than is general in America. Tungsten was definitely favored as an alloying element for most hot work die steels. One widely used series contained about 4.5% tungsten and 1½% chromium and was made in several carbon ranges from as low as 0.24 to as high as about 0.45.

Toolsteels for cold work likewise follow the pattern of American practice, but it was noted there was a considerable lack of die steels of the air hardening variety in which molybdenum was used as the principal contributing element to obtain the air hardening qualities. As a matter of fact it is significant that the entire German industry did not take advantage of the properties molybdenum imparts to steel.

Table III—Krupp "Zeus EA" Electrodes for Hard Surfacing

GRADE	C	Si	Mn	Cr	Co	W	Ti	OTHER
Mangan	1.15	0.30	14.0					
V 13 F	0.12	0.45	0.30	13.0				0.20 Ni
V 17 F	0.10	0.45	0.30	17.5			7 × C	0.20 Ni
150	0.20	0.35	1.0				0.20	
250	0.25	0.35	1.6				0.20	
F 20 S	1.6	0.9	0.20	20.0				
F 20 SH	2.5	0.9	0.20	20.0				
F 28 S	1.6	0.9	0.55	28.0				
F 28 SH	2.1	0.9	0.55	28.0				
Diaweld	4.1	1.8	5.5	30.0				
GA 350	0.45	0.35	2.1	1.15			0.20	
GA 500	0.90	0.35	2.1	1.3			0.20	
Percit Extra	1.10	2.5	0.40	27.0	60.0	4.3		
Percit Special	1.50	1.45	0.40	27.5	32.5	4.25		
NFKC	1.40	0.22	0.30	0.45		3.25		0.25 V
KFM	0.95	0.30	0.30	3.75		1.35	0.12	2.8 V*
DFMV 5	1.35	0.30	0.30	4.25		10.5		4.35 V

*Plus 2.35% molybdenum

A place for metallurgical and production ideas; an A.S.M. book of your choice for publishable items

Identification of Specimen Mounts

THERE are apparently as many ways to identify specimens in transparent mounts as there are ways of cooking eggs. We often use non-transparent plastic, and so we put a "window" on the bottom!

First of all we prepare a disk of transparent plastic the same diameter as the mount and about $\frac{1}{32}$ in. thick. The specimen to be mounted is placed in the bottom of the mold and filled round with bakelite powder in the usual way. A slip of card somewhat smaller than the diameter of the mount and carrying the necessary identification particulars is then placed on top of the powder, face upwards, the lucite disk put on top of it and the whole lot heated and compressed.

The pre-fabricated thermo-plastic transparency bonds perfectly well with the bakelite, and the finished mount carries its identification marking clearly visible, and fully protected by the lucite window against damage by handling, moisture and other causes. A suitable stock of lucite disks can be made in the mounting press in odd moments, ready for use when required. (E. SIMISTER, Metallurgist, Kirkstall Forge, Ltd., Leeds, England)

Low Tempering After "Deep Freezing"

SUB-ZERO treatment or "deep freezing" of tool-steels has recently been a much discussed subject in the technical press. Many of the metallurgical aspects and certain advantages have been made known. However, the importance of the temperature to which the tools can be heated without softening *after* sub-zero cooling has only been dealt with perfunctorily.

Quenching toolsteel to room temperature retains approximately 20% untransformed austenite; if the part is then quenched to low temperatures (say, -110° F.) the untransformed austenite is reduced to approximately 10%. It

has also been shown that the tempering characteristics of the refrigerated sample are different from that of the normally quenched sample, due presumably to some difference in the martensite formed. Thus, the martensite formed in the normal quench is not affected by secondary hardening—that is, on heating to 1075 to 1100° F. the hardness of the part remains constant or increases—whereas the martensite formed in deep freezing softens if heated to the same normal temperatures.

An example of this follows: Some tools were hardened by deep freezing and gave an average hardness of 950 by the Vickers diamond penetrator. After tempering at 1085° F. for 1 hr. the hardness averaged 825. Tools of a similar composition were also deep frozen and tempered at 950° F. for 1 hr. and averaged 900 hard.

It will thus be seen that the advantages of deep freezing can be lost to some extent by tempering at too high temperatures, and it would appear from results so far obtained in my experience that the most suitable temperature for relieving internal stress and at the same time obtaining maximum hardness on deep frozen tools is close to 950° F. (C. A. E. WILKINS, Metallurgist, Albion Motors, Ltd., Glasgow, Scotland)

Test for Passivated Stainless Steels

IT IS FREQUENTLY NECESSARY to be able to detect ferritic iron on the surface of austenitic stainless steel or non-ferrous metal surfaces, to determine for example where iron tools have scratched the surface or where iron has perforated the stainless-clad surface of new tanks. The test depends upon the red color formed by ferric salts with acetoacetates, and it was developed by the research departments of International Nickel Co. and Union Carbide & Carbon Corp.

The following formulas have been used successfully for some time:

Solution A—68 g. of acetoacetanilide to 1 liter of acetone.

A Scientist Reports on Hiroshima

Excerpts from testimony before the Senate's special committee on atomic energy by Philip Morrison, nuclear physicist from Los Alamos laboratory, who inspected Hiroshima after the bombing.

THE ATOMIC BOMB is a weapon of saturation. It destroys so quickly and so completely such a large area that defense is hopeless. Leadership and organization are gone. Key personnel are killed. With the fire stations wrecked and firemen burned, how control a thousand fires? With the doctors dead and the hospitals smashed, how treat a quarter of a million injured?

There is one more novelty. A Japanese official stood in the rubble and said to us: "All this from one bomb; it is unendurable." We learned what he meant. The cities of all Japan had been put to flame by the great flights of B-29s from the Marianas. But at least there was warning, and a sense of temporary safety. The thousand-bomber raids were not concealed; they even formed a pattern of action which the war-wise Japanese could count on. But every hour of every day above any Japanese city there might be one American plane. And one bomber could now destroy a city. The alert would be sounded day and night. Even if the raiders were over Fukuoka, you in Sendai, a thousand miles north, must still fear death from a single plane. This is unendurable.

When the bomb is detonated in the middle of a city, it is as though a small piece of the sun has been instantly created. There is formed what we have called the ball of fire, which is a hot, glowing mass something about one-third of a mile across, with a temperature of about 4,000,000° F. in the center of it. The effects from this small sun are as you would expect. There is a sudden creation and expansion which pushes away, with terrible violence, the air that once occupied this region.

This air, shocked into motion, as we say, moves just like a blast wave from a great explosion of TNT. Behind the wave of pressure, which travels rapidly through the air, there come great winds, 500 to 1000 miles per hr.,* winds which damage and destroy all structures.

*A wind of hurricane intensity may reach 120 miles per hr.

There is not only the concentrated heat which you would expect from being close to the sun, there is also a great amount of radiation, like the radiation used by doctors, like the X-ray radiation used for the treatment of cancer. This radiation is very penetrating. There is no protection behind a foot of concrete, for example.

The damage done is not easy to realize. Houses and buildings for a mile in all directions are totally destroyed. A good deal of comment has been attracted by the ferro-concrete structures whose walls still stand. These are very strong buildings. But they too are useless. I have been in these buildings. The interior walls are down, the roofs are collapsed, the furniture battered, plumbing fixtures and heavy machinery overturned. Brick buildings, and even steel-frame buildings with brick walls are extremely vulnerable.

Of these people within 1000 yd. of the blast, about one in every house or two escaped death from blast or from burn. By chance these people were screened from the heat of the bomb by some object too light or too strong to kill them by falling upon them. Many literally crawled out of the wreck of their homes relatively uninjured. But they died anyway from a further effect, the effects of radium-like rays emitted in great number from the bomb at the instant of the explosion. This radiation affects the blood-forming tissues in the bone marrow, and the whole function of the blood is impaired. The blood does not coagulate but oozes in many spots through the unbroken skin, and internally seeps into the cavities of the body. There might be a slight burn on the skin, but it was not essential. The white corpuscles which fight infection disappear. Infection prospers and the patient dies, usually two or three weeks after the exposure.

Like all nuclear physicists, I have studied this disease a little. It is a hazard of our profession. With the atomic bomb, it became epidemic.

Solution B—112 g. of ammonium acetate to 1 liter of distilled iron-free water.

Procedure—Weigh the required amount of white, solid acetoacetanilide and crystalline ammonium acetate in separate containers. Measure the amount of acetone required for Solution A, pour it over the acetoacetanilide, and stir until dissolved. Measure the amount of iron-free water for Solution B, pour it over the ammonium acetate, and stir until dissolved. The two solutions are mixed as needed by measuring 4 volumes of

A to 1 volume of B. The mixture turns brown within 48 hr. and must be discarded.

The solution may be applied to the surface to be tested with a paint brush, an eye dropper, or a small atomizer. It spreads over the surface and dries quickly. The surface turns blood red in 3 min. (or less) if the surface contains free iron (ferrite). If the dry surface is white, gray, or light pink in color the test for iron is negative. A negative test is given by passivated 18-8 chromium-nickel stainless steel. The solution does

Big Three's Resolution on Atomic Energy

AT THE MEETING which took place in Moscow from Dec. 16 to Dec. 26, 1945, of the ministers of foreign affairs of the Union of Soviet Socialist Republics, the United States of America and the United Kingdom, agreement was reached on the following questions:

SEVEN — The establishment of a Commission for the control of atomic energy.

Discussion of the subject of atomic energy related to the question of the establishment of a commission by the general assembly of the United Nations. The three ministers have agreed to invite the other permanent members of the Security Council, France and China, together with Canada, to join with them in assuming the initiative in sponsoring the following resolution at the first session of the General Assembly of the United Nations in January, 1946:

Resolved by the General Assembly of the United Nations to establish a Commission, with the composition and competence set out hereunder, to deal with the problems raised by the discovery of atomic energy and other related matters.

I. Establishment of the Commission:

A Commission is hereby established by the General Assembly with the terms of reference set out under Section V below.

II. Relations of the Commission with the organs of the United Nations:

(a) The Commission shall submit its reports and recommendations to the Security Council, and such reports and recommendations shall be made public unless the Security Council, in the interests of peace and security, otherwise directs. In the appropriate cases the Security Council should transmit these reports to the General Assembly and the members of the United Nations, as well as to the economic and social council and other organs within the framework of the United Nations.

(b) In view of the Security Council's primary responsibility under the charter of the United Nations for the maintenance of international peace and security, the Security Council shall issue directions to the Commission in matters affecting secu-

urity. On these matters the Commission shall be accountable for its work to the Security Council.

III. Composition of the Commission:

The Commission shall be composed of one representative from each of those states represented on the Security Council, and Canada, when that state is not a member of the Security Council. Each representative on the Commission may have such assistants as he may desire.

IV. Rules of procedure:

The Commission shall have whatever staff it may deem necessary, and shall make recommendations for its rules of procedure to the Security Council, which shall approve them as a procedural matter.

V. Terms of reference of the Commission:

The Commission shall proceed with the utmost dispatch and inquire into all phases of the problem, and make such recommendations from time to time with respect to them as it finds possible. In particular, the Commission shall make specific proposals:

(a) For extending between all nations the exchange of basic scientific information for peaceful ends;

(b) For control of atomic energy to the extent necessary to insure its use only for peaceful purposes;

(c) For the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction;

(d) For effective safeguards by way of inspection and other means to protect complying states against the hazards of violations and evasions.

The work of the Commission should proceed by separate stages, the successful completion of each of which will develop the necessary confidence of the world before the next stage is undertaken.

The Commission shall not infringe upon the responsibilities of any organ of the United Nations, but should present recommendations for the consideration of those organs in the performance of their tasks under the terms of the United Nations charter.

not color on black mill scale but it gives a positive test on a steel surface cleaned by machining, pickling, or sand blasting. It does not color on a surface coated with mineral acids (such as from a pickling bath) but gives a test when the acid is neutralized or removed by washing.

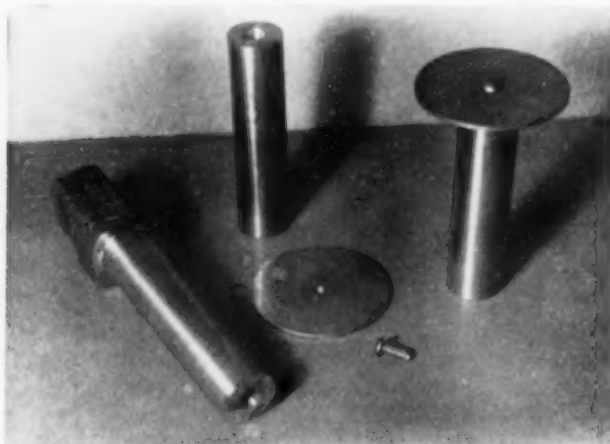
Remarks — The acetone content has made the solution combustible; keep it away from open flames or hot metal. Acetone evaporates quickly, however, and the fumes are not toxic in the concentration normally present. The mixed solution has been used for testing tank interiors and other closed equipment. The acetoacetanilide residue left on the surface can be removed by wiping with

a rag or dissolving it in hot water, toluene, or acetone. (EUGENE E. EVERETT, Process Engineer, Air Technical Service Command, Delco-Remy Division, General Motors Corp.)

Manufacture of End-Quench Test Bars

IN ORDER to speed up machining of Jominy test pieces we felt that we should eliminate the shoulder on the end to allow a straight cut. By using some scrap punchings and a drive screw we had not only a means of holding the bar in the fixture, but also a cover for the container in

*Rough Turned Bar, Pieces Ready for Assembly,
and the End-Quench Bar Ready for Testing*



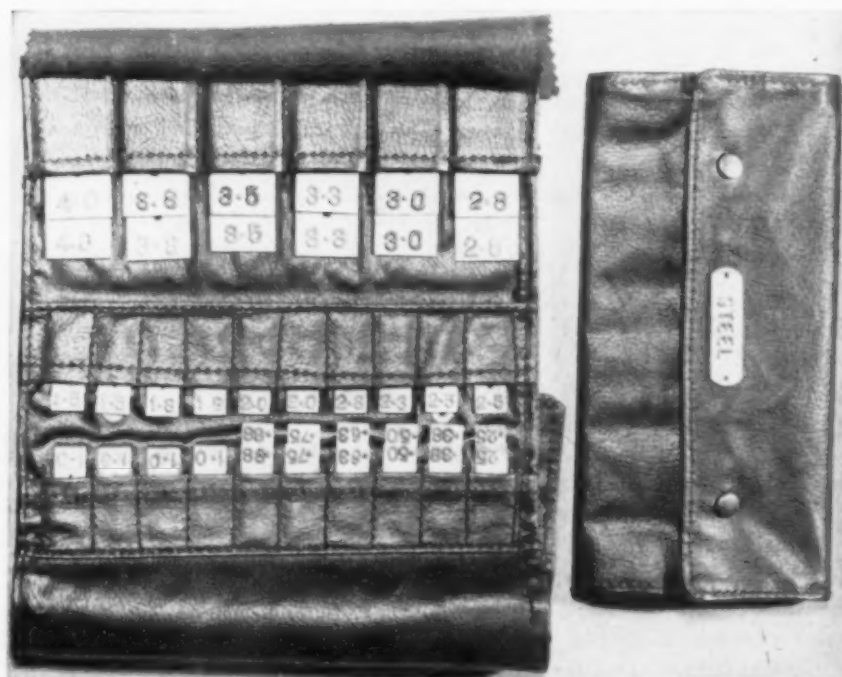
which we heated the sample. The screw is a 10x $\frac{1}{2}$ -in. Parker-Kalon, and the countersunk center has a pilot equal to a No. 20 drill.

It now takes about 5 min. to prepare a Jominy bar from a cast bar when using a carbide tipped lathe tool on a high speed lathe. Previously the time was about 40 min. with the shoulder-type bar turned on a slower lathe using high speed tools. (THOMAS G. BUSACK, Metallurgist, Symington-Gould Corp.)

Penetrometer Cases

MOST industrial radiographers are acquainted with the serious problem of lost or damaged penetrometers — particularly for 0.25 and 0.38-in. material. This problem was completely overcome by the case shown at right. It is designed to hold two complete sets of penetrometers for metal thicknesses up to 4 in. There is an individual case for each type of metal. The dimensions of the case closed are 4 by 8 in. and it has a felt flap that prevents damage to the penetrometers.

A negligible number of penetrometers have been lost or damaged since using these cases. No replacements have been required in the last six months against a previous record of approximately 10 penetrometers per month. (MERLE F. VALADE, Chemical & Metallurgical Dept., Ford Motor Co.)



*Case for Penetrometers for Use on Steel
Sections From 0.25 to 4.0 In. Thick*

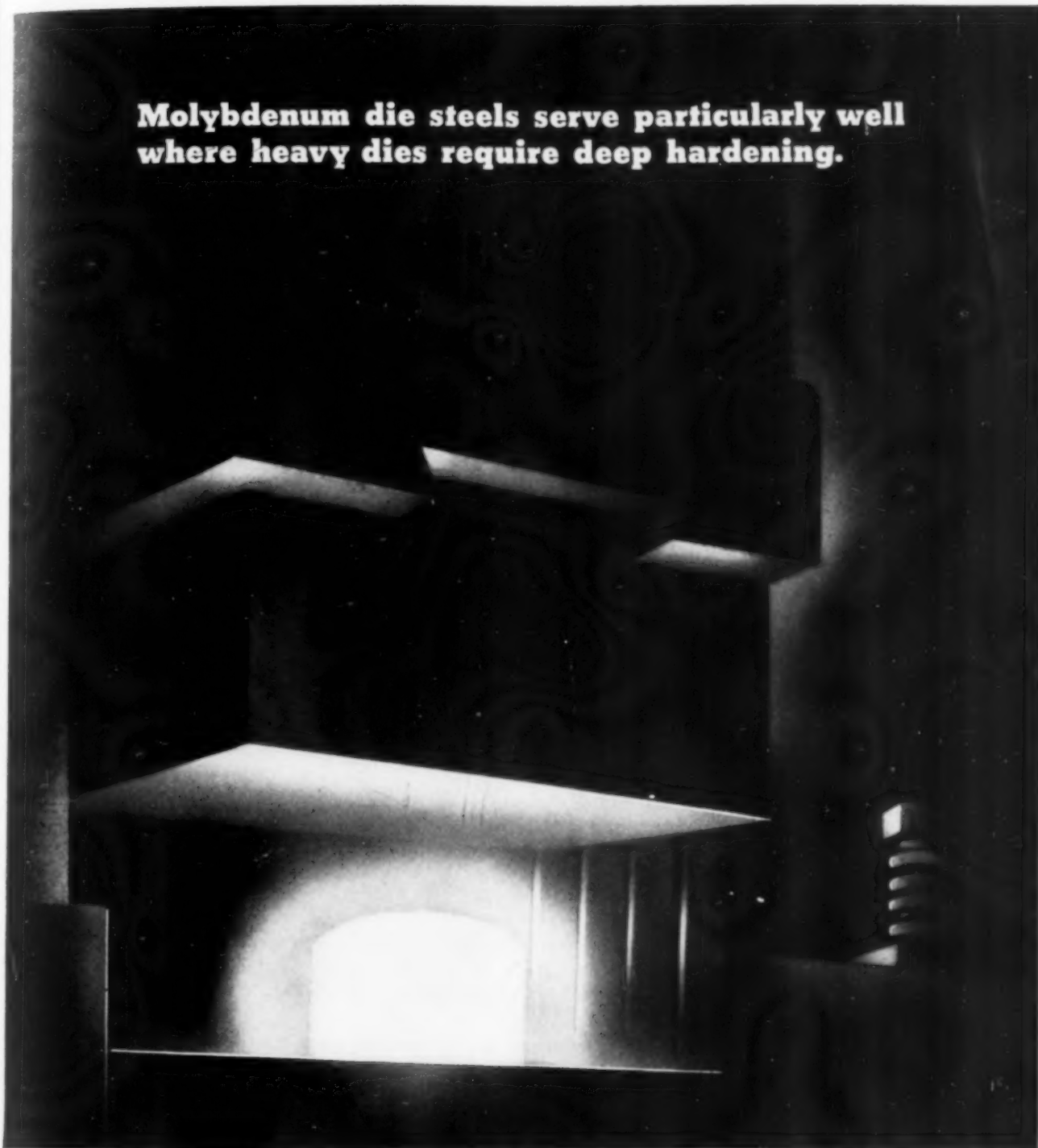
Mounting Porous or Scaled Specimens

PRESSURE MOLDING of mounts is not always suitable for intricate sections, nor does it always provide adequate support for porous or friable sections such as oxide scales. For these the following technique has been used successfully:

A suitable size mold is made from brass tube squared off at the ends and cemented to a flat base (glass slide). The specimen rests on the glass on the face to be polished, and the mold is filled to a convenient depth with liquid bakelite cement — slightly warm for better fluidity. It is then placed in a vacuum desiccator and connected to a vacuum pump which removes air bubbles; all open pores, cracks and various intricacies become filled with bakelite when the vacuum is released.

To harden the bakelite cement it has to be heated for several hours at 60 to 70° C. to drive off the solvent, with a final heating at about 110° C. in a drying oven to complete the polymerization. It is advisable to avoid forcing the pace in the evaporation stage or the liquid will boil up and harden as a porous mass. A small tag can be pressed into the bakelite for identification while this is still soft. There is a slight contraction on final hardening, so the mount can be removed quite easily from the mold, ready for grinding and polishing. (E. SIMISTER, Kirkstall Forge, Ltd., Leeds, England)

**Molybdenum die steels serve particularly well
where heavy dies require deep hardening.**



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Personals

R. M. GRANT ☉ is sales engineer for Orr & Sembower, Chicago, Illinois.

C. R. HECKER ☉ left the E. F. Houghton & Co. to become eastern branch manager for the Nox-Rust Chemical Corp., Chicago.

MARK H. KERN ☉ is now assistant spectrographer with the A. O. Smith Corp., Milwaukee, Wis.

H. C. SCHLANPITZ ☉, formerly with the Aluminum Co. of America, is now electroplating engineer at the Napier Co., Meriden, Conn.

Following many years of service with the Canadian General Electric Co., F. R. BARNSEY ☉ has recently been appointed manager of the supply division of the Vancouver district office.

ALEXANDER M. BROWN ☉ has returned to Cherry Burrell Corp., New York City, since his release from the Army.

H. E. COPELAND ☉, formerly with Minneapolis-Honeywell Regulator Co., has been appointed superintendent of the Alloy Division, Michigan Products Corp., Michigan City, Ind.

JOSEPH J. TOMPOS ☉, formerly with the Standard Steel Spring Co., is now metallurgist in the quality control division of the Carnegie-Illinois Steel Corp., Pittsburgh.

The Coldset Diamond Tool Co., Fort Lee, N. J., has secured the services of CARL SJOLANDER ☉.

R. C. DALZELL ☉ has been transferred from the Ordnance Division of Revere Copper and Brass, Inc. to the general offices at Rome, N. Y., where he will be chief technical advisor to the company.

H. V. BORDEAUX ☉ has been appointed engineering service representative of Sterling Alloys, Inc. in California.

MARCUS M. CHAPMAN ☉ has been made manager of sales in the sheet division of the United States Steel Corp. following many years of service with this company.

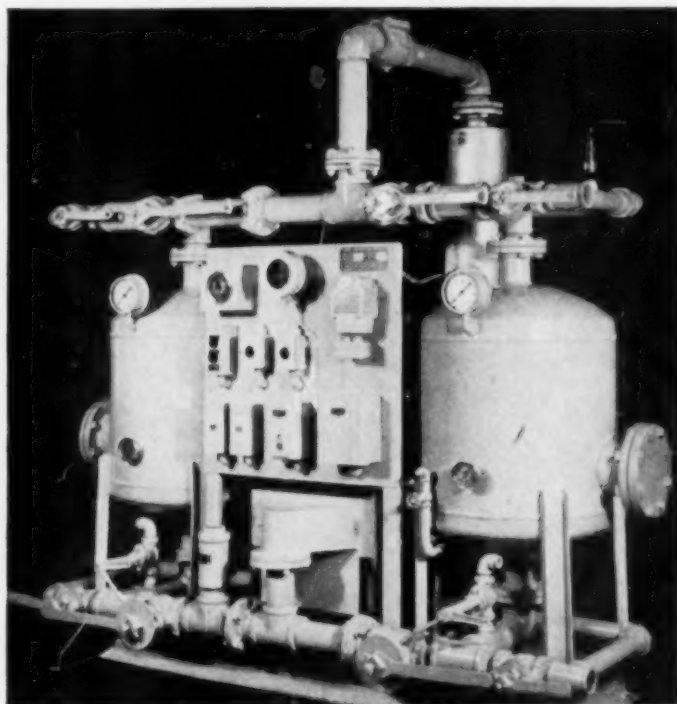
ALFRED C. WOOLL ☉ is now with the Aluminum Research Laboratories of the Aluminum Co. of America, New Kensington, Pa.

DEAN K. HANINK ☉, formerly with the Dodge Chicago plant, is research metallurgist in the General Motors Research Division.

GEORGE R. PEASE ☉ has left the Springfield Armory to join the research staff of The International Nickel Co., at the plant in Bayonne, N. J.

FRED A. HARRIS ☉, formerly metallurgist for the Tennessee Metallurgy Co. and chemist for the Nashville Division of Consolidated Vultee Aircraft Corp., is now associated with the Phosphate Mining Co. of Nichols, Florida, as metallurgist and chemist.

HENRY S. RAWDON ☉ has retired from his position as chief of the Division of Metallurgy at the National Bureau of Standards, after some 33 years of noteworthy service with that institution. He will continue to represent the Bureau on a number of technical committees, but will devote most of his time to his country place near Washington. His new address is RFD 3, Bethesda 14, Maryland. (A biographical note and appreciation was published in *Metal Progress* for September 1943.)



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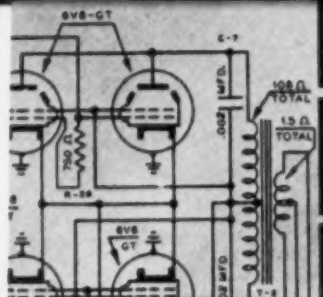
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DOCUMENT RECORDING shows drawings, documents, records, etc. to all interested in large- or small-scale copies of original material.

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ESSENTIALLY PRACTICAL, Functional Photography more than pays its way. Reflecting the expanding needs of modern business and industry, it harnesses for those needs photography's unique powers to show . . . to record and reproduce information, much of which is beyond the ability of human vision.

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uses . . . showing new ways to faster processes, sounder techniques, lower costs, and more efficient administration in today's highly competitive world.

Highlighted here are a dozen examples of Functional Photography which provide a brief introduction to the wide variety of photography's uses in business and industry. Investigate their possibilities in your operations.

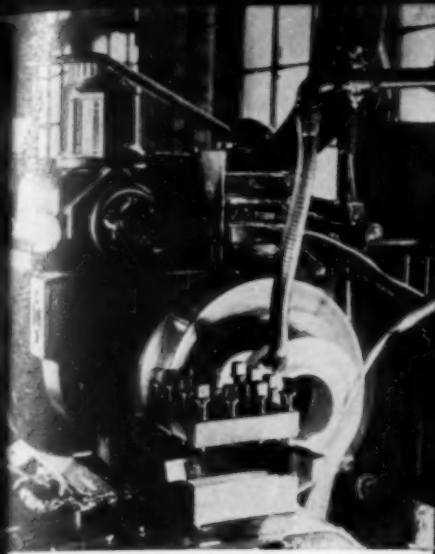
Eastman Kodak Company, Rochester 4, N.Y.

You will be welcome at the Kodak Exhibit. If you are planning to attend the 27th Metal Congress Exposition in Cleveland, be sure to see the Kodak Functional Photography exhibit, booths B409 and B415. It will help you determine photography's usefulness in your business. If you are not attending, write for new twenty-page "Functional Photography" booklet.

INSTRUMENT RECORDING shows electrical or mechanical phenomena too rapid for the eye to follow. Provides a record for reference.

PHOTOMICROGRAPHY shows changes in grain structure caused in material by metal-working, heat-treating, etc. at magnifications up to 5,000 diameters.

PHOTO-VISUALS show workers how to perform production operations graphically, quickly, and inexpensively.



ULTRA-SPEED PHOTOGRAPHY shows action too fast for the eye to follow by stretching split seconds into minutes.

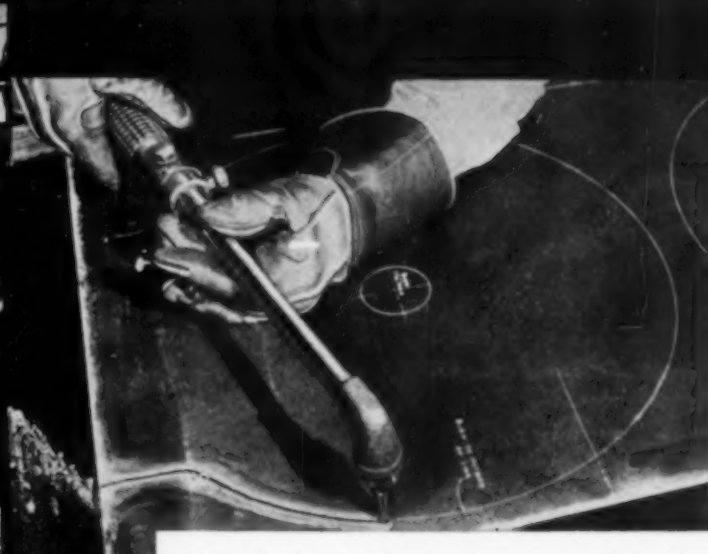
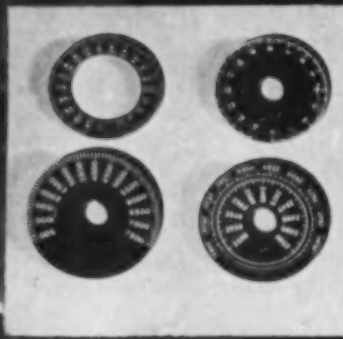
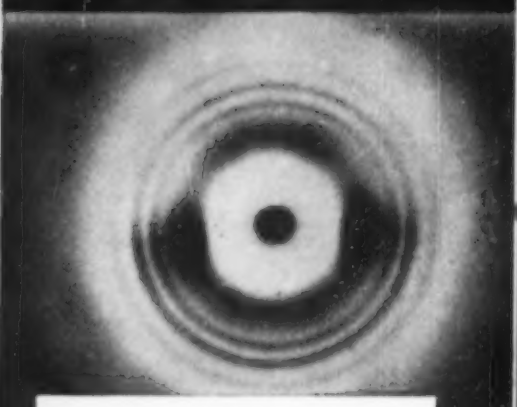


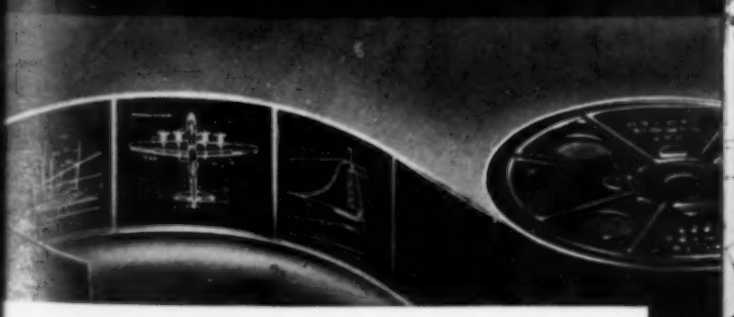
PHOTO LAYOUT shows dimensions and working instructions in full scale on the metals, plastics, or other material in production. Excellent for templates and precision dials, wiring diagrams, etc.



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Personals

N. H. CALE ☼, formerly with the Canada Strip Mill, Ltd., is now in the technical department of the American Brass Co., Waterbury, Conn.

JOHN A. FELLOWS ☼ resigned from his position as assistant chief metallurgist of the American Brake Shoe Co. to become affiliated with the Carbide & Carbon Chemicals Corp.

CLINTON E. SWIFT ☼ is now manager of engineering and research of the Greenleaf Corp., Pittsburgh.

HERBERT F. BROWN ☼ has re-joined the American Gas Furnace Co., Elizabeth, N. J., following his release from the U. S. Army.

ROBERT M. KINNEY ☼, formerly with Remington Rand, Inc., is now a member of the sales department of the Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia.

WILLIAM T. GRIFFITHS ☼, of London, has been elected vice-president and director of The International Nickel Co. of Canada, Ltd.

EVAN N. DAVIDENKO ☼ is now chief metallurgist, Solar Precision Castings Co., Des Moines, Ia.

FRANK B. DAVIS ☼ has been made New England district manager for the Copperweld Steel Co. with offices in Hartford, Conn.

CURTIS L. GRAVERSEN ☼ has resigned as metallurgist for the AC Sparkplug Division of General Motors to accept a research fellowship at the University of Utah to continue his studies in the field of metallurgy.

Transferred to the metallurgical department, reduction division, of the Massena plant of the Aluminum Co. of America: JACK A. LANG ☼, formerly at the Mead (Spokane) plant.

GUSTAV JEBENS ☼, formerly with the Allison Division of General Motors, is now heat treat foreman of John Deere Plow Works, Davenport, Iowa.

News about metallurgical friends in France is slowly becoming available. NICHOLAS BELAIEW, a Russian artillery officer remaining in France after World War I and an early scientific student of the ingot phase of steel manufacture, reports that many visiting American metallurgists have called upon him at his home at 1 Rond-point Bugoud in Paris. Professor PORTEVIN, the faithful correspondent to *Metal Progress*, was separated from his family during most of the war, he being in Paris and they in Blois ("the journey at times being very tiring indeed") but they are now reunited in their Paris flat.

SHELDON H. REYNOLDS ☼ is now field engineer of the National Tube Co., Houston, Texas.

VINCENT D. BARTH ☼, previously with Douglas Aircraft, is now process engineer for Federated Metals Division, American Smelting and Refining Co., Detroit.

Having terminated his connection with General Motors, L. WAYNE SINK ☼ is now metallurgist in the Bearing Division, P. R. Mallory & Co., Inc., Indianapolis.

JAMES E. LEWIS ☼ formerly with the Raymond Mfg. Co., is now with the L. G. S. Spring Clutch Corp., subsidiary of the Curtiss-Wright Corp., as sales engineer.



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more of electrodes of any size.

Need design help? If you need aid in adapting this rack to your plant, or have a special electrode storage problem, National Carbon engineers will be glad to assist.

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 Kansas City, New York, Pittsburgh, San Francisco

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Personals

FRED C. T. DANIELS ☼, vice-president of Mackintosh-Hemphill Co., Pittsburgh, has recently returned from a month's tour and study of the steel industry of England and France.

Allegheny Ludlum Steel Corp. announces the appointment of P. E. FLOYD ☼ as manager of sales of a new carbide alloy sales division, Ferndale, Mich.

RALPH E. RECKTENWALD ☼ is now sales engineer for the Minnesota territory representing Honan-Crane Corp., subsidiary of Houdaille-Hershey Corp.

DANIEL L. GARLAND ☼ is now chemical engineering supervisor in the materials laboratory of the Wright Aeronautical Corp., Paterson plant.

Glenn L. Martin Co. has transferred CHARLES F. BURROWS ☼ from the Nebraska Co. to be research metallurgist at the Baltimore plant.

BERNARD J. EGAN ☼, formerly with the Radio Corp. of America, is now assistant methods engineer, Revere Copper and Brass, Inc., Rome, N. Y.

H. G. LINDBERG ☼ is now with the Chrysler Corp., Highland Park, Mich.

P. W. ROLLESTON ☼ is now affiliated with Aluminium Laboratories, Ltd., Banbury, England.

E. V. CRANE ☼ has been made vice-president of Sam Tour & Co. of New York City. He will be in charge of mechanical engineering, metal working projects and research. He was for many years with the E. W. Bliss Co.

WILLIAM A. VENSEL ☼, formerly with the Detrex Corp., has opened his own business selling industrial lighting equipment under the name of Southworth Co. in Los Angeles.

Carnegie Institute of Technology, Pittsburgh, has appointed WILLIAM O. PHILBROOK ☼ to be assistant professor of metallurgical engineering and a member of the staff of the Metals Research Laboratory.

GEORGE S. KENDIG ☼ has organized a new heat treating firm in Detroit, known as Heat Treat, Inc.

ROGER A. LONG ☼, formerly with the National Smelting Co., is now metallurgist in the Bearing Division of the P. R. Mallory & Co., Inc., Indianapolis, Ind.

J. L. SPENCE ☼ and G. W. PATERSON ☼ will manage the Refractories Engineering and Supplies Co. of Canada, representative of The Charles Taylor Sons Co. of Cincinnati, Ohio.

JOHN N. CARLSON ☼ is Philadelphia representative of the Quaker Chemical Products Corp. of Conshohocken, Pa.

CLARENCE H. SAMPLE ☼, formerly a member of the technical staff of the Bell Telephone Laboratories, has joined Rheem Research Products, Inc., Baltimore, as chief engineer.

Formerly with the Procurement Division (Lend-Lease), U. S. Treasury Department, HUGH H. HUNTER ☼ has accepted a transfer to the Detroit sales office of the Reconstruction Finance Corp.

CHESTER V. NASS ☼ has been elected vice-president of the Pettibone Mulliken Corp., Chicago. He has been manager of the foundry division since 1942.

Are you informed about the *new* Titanium Steel for Vitreous Enameling



LABORATORY-TESTED and plant-proved are the advantages of this *new* Titanium steel to manufacturers of vitreous enamel products, when recommended practice is followed in steel making, pickling and enameling.

By removing source of reboil in the stock, large cost reductions are possible. Ground coat can be eliminated and conventional cover coats may be applied directly. Sagging is minimized, and hydrogen penetration is sharply reduced.

Lighter weights of enamel are possible, yielding a greater resistance to thermal shock. Drawing properties are equivalent to that of the best drawing steel.

Manufacturers of both steel and enameled products may obtain complete technical data from a member of our Technical Staff. Consult your steel supplier for deliveries.



Pending patent applications on the new enameling process and product made therefrom are owned jointly by Inland Steel Company and The Titanium Alloy Manufacturing Company under Trust Agreement.

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For HEAT TREATING, FORGING AND BROACHING OPERATIONS



Three of a battery of Stewart Forge Furnaces at Snap-on Tools Corporation. The operator in the foreground is cooling his tongs prior to removing heated bar stock. The raw bar stock (A) goes to the Stewart Forge Furnace (B) thence to the Forge Hammer (C). Behind the Forge Hammer units are located trimming and punching-out presses.

Typical of the many instances where Stewart Industrial Furnaces are meeting the production forging requirements for small tools and parts is this installation at Snap-on Tools Corporation, Kenosha, Wis.

The large forge shop is equipped with five hammer forges, ranging from 800 to 2000-pound capacities, for necessary forging operations. Each hammer forge has conveniently installed by its side a Stewart Forge Furnace for quick, easy, labor-saving handling of heated bar stock. There are seven Stewart Forge Furnaces installed throughout the shop.

Two Stewart Indirect Fired, Oven-type Furnaces have been installed for stress relieving and annealing after forging. This is a versatile Stewart Furnace because it will handle anything from a small tool to a large casting or weldment. Or it will heat a container full of small pieces.

The Punch Press Department, where broaching-out socket wrenches is done, employs twenty Stewart Oven Furnaces. All have hopper-style feeds in the rear for handling the material to be heated for necessary broaching operations.

These Stewart Furnaces are typical of the dependable industrial furnaces Stewart engineers have built in the past and will continue to build today and tomorrow—both large types to meet the specified requirements of manufacturers all over the continent, as well as standard types.



Operator clearing broached parts from press after being heated in the Stewart No. 26 Oven Furnace on his right.



Operator at large Punch Press used for broaching-out large hexagon holes. Here again, the Stewart Furnace is located close to the press to reduce the handling time between furnace and press and to keep work from cooling off before it goes into the press.

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A letter, wire or 'phone call will promptly bring you information and details on STEWART furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a STEWART engineer will be glad to call and discuss your heat treating problems with you.

Porosity in Non-Ferrous Castings*

THE MOST OBSTINATE sources of defects in castings are the volume changes in cooling metals, especially the shrinkage during solidification, and the absorption and liberation of gases from metals.

The principal factors involved in the formation of shrinkage defects are, first, the magnitude of the volume change, especially of the freezing shrinkage which also promotes hot tears and internal

stresses, and second, temperature gradients in the casting, yet good feeding is promoted by steep temperature gradients toward the feeder head. In castings solidifying in more than one direction, there is an optimum overall rate of solidification for each particular casting. This optimum rate is higher, the nearer the approach to unidirectional solidification.

Temperature gradients in the

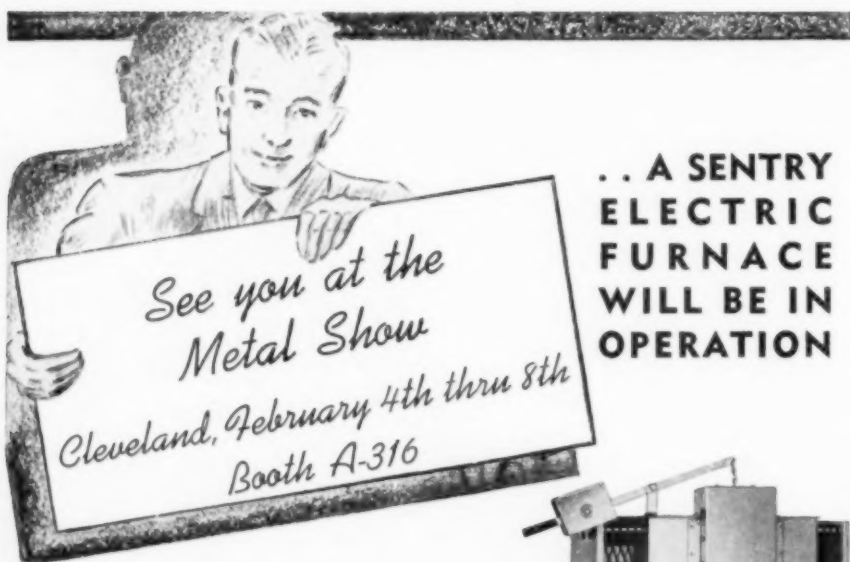
casting are influenced by (a) sectional thickness of the casting and local variations; (b) relative volumes and shapes of the feeder and casting; (c) the thermal capacities and conductivities of the metal and mold; (d) the freezing temperature or range of the metal; (e) pouring temperature and mold temperature; (f) method of feeding the mold; and (g) pouring speed. Factors (a), (c), and (d) are predetermined so the desired conditions of solidification must be secured by control of the others. Of these variables the method of filling the mold is generally the most important.

The efficiency of feeding and the form and distribution of shrinkage porosity or external cavities may be largely influenced by other properties of the metal including (a) composition of the alloy; (b) mode of the crystal growth and the grain size; and (c) the physical properties of the feeding liquid, particularly its viscosity and the surface tension of the residual liquid between the primary crystals. This last condition is probably not amenable to control and (b) is largely determined by the metal used—although grain size is frequently controllable. The constitution of the alloy is probably the most important of all. Where possible, metals and alloys should be used in which a eutectic predominates, since they are least susceptible to hot tearing and interdendritic fissures.

The design of the casting and the rigidity of the mold are important factors, together with temperature gradients, and efficiency of feeding, which influence the incidence of hot tears and internal stresses.

Sources and effects of gas porosity are: (a) Element gases, notably hydrogen, may be dissolved by the molten metal and liberated during solidification with the resultant formation of gas-filled cavities. (b) Compound gases, notably water vapor and oxides of carbon and sulphur, may be dissolved in the molten metal and the gas liberated during solidification; their rate of diffusion is much lower than that of hydrogen and consequently these gases are more likely to be trapped in the casting and to cause porosity. (c) Gases come from the melting furnace atmosphere. It is common to melt (Cont. on p. 140)

*Abstracted from "Shrinkage and Gas Effects in the Casting of Non-Ferrous Metals and Alloys", by W. A. Baker, Research Report of British Non-Ferrous Metals Research Association, No. R.R.A. 661, June 1944.



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WILL BE IN
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Sentrys assure correct hardness, true-to-size work, scale-free with no decarburization. Heat treat your tools and parts scientifically using Sentry Diamond Block controlled neutral atmosphere.

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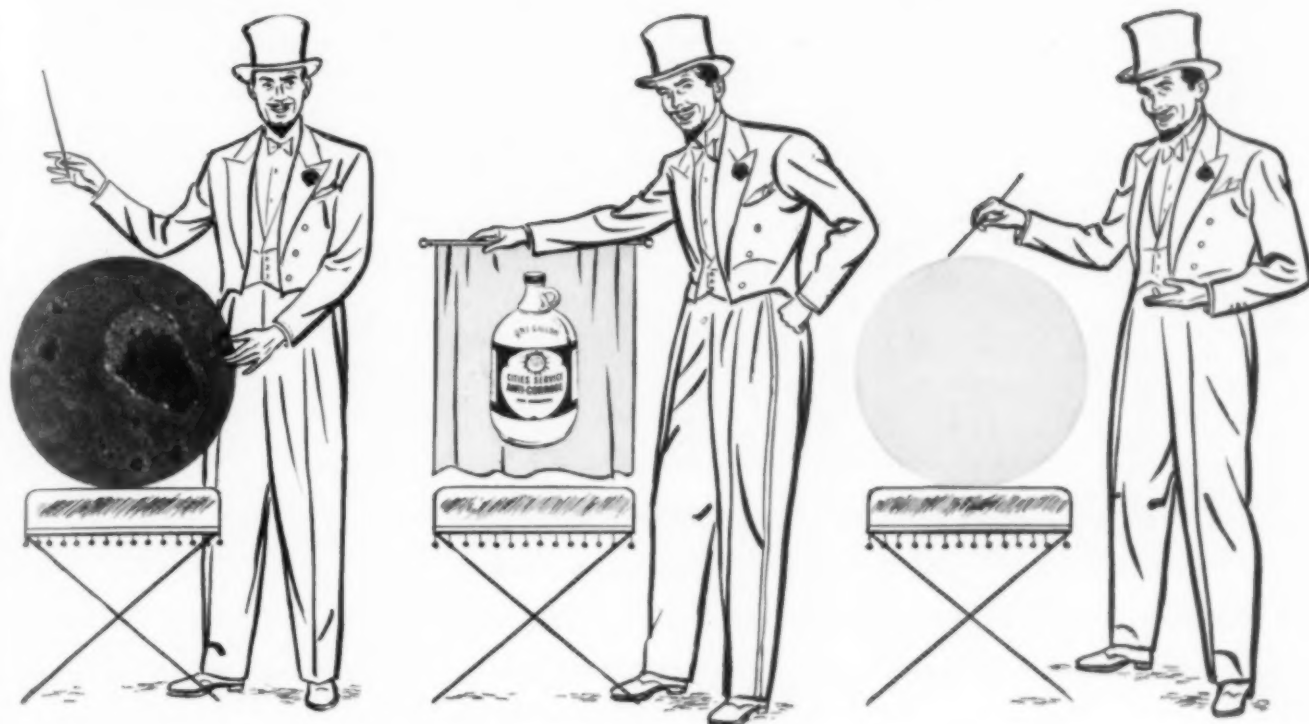


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Porosity in Non-Ferrous Castings

(Cont. from p. 138) many metals in oxidizing atmospheres to prevent solution of reducing elements but this is effective only when the metal will dissolve oxygen. (d) Hydrogen may enter the metal during solidification in the mold. (e) The properties of well-fed castings are impaired by gas porosity, but in badly fed castings the presence of gas may serve to disperse shrinkage porosity.

The practical recommendations are as follows:

Shrinkage Defects. Of all the variables in the casting process, the method of filling the mold is the most important one which may be conveniently varied. Each casting must be treated individually, but the first poured metal should reach the parts of the casting remote from the feeder where it will soon become cold and the last poured metal will remain hot in the feeder. Direct pouring at a controlled rate is strongly recommended; where drossing difficulties make this impractical, the middle running, side running, or inversion methods should be used to promote directional solidification towards the feeder. Bottom running technique should be avoided. These recommendations will minimize shrinkage porosity but also will materially reduce the danger of other shrinkage defects such as hot tears and internal stresses. Whenever possible, eutectic alloys should be used.

Gas Defects. Excessive amounts of dissolved gas may be removed by pre-solidification (which is tedious and not recommended), by scavenging with an inert gas (which is generally applicable for the removal of hydrogen), and by oxidation-reduction treatment (which is not applicable to alloys with appreciable amounts of aluminum, magnesium, zinc, phosphorus, manganese and silicon since these elements so lower the solubility of oxygen that neither can gas unsoundness involving oxygen occur nor can the reducing element be displaced by oxidation treatment).

Moderate amounts of dissolved gas may sometimes be beneficial and can be secured by treatment with controlled gas mixtures or by control of melting practice, or the metal may be degassed and then gassed by the addition of suitable amounts of hydrated salts. ☉

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MAIL the coupon below for this free test panel of Iridite-protected zinc plating. Have your laboratory give it any corrosion test you want. Watch Iridite "take it" and come back for more. Then you'll see for yourself why Iridite is so widely used as a corrosion-resistant final finish by such manufacturers as Western Electric, Otis Elevator, Bulova, Pyrene, Anaconda and many others.

Watch, too, as you're testing it, how the color holds up . . . remains a uniform shade. And remember, Iridite is available in a wide range of colors, adding to products the sales appeal that comes from attractive appearance. Also, because of Iridite's excellent qualities as a paint base, all colors can be clear-lacquered for even greater durability!

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Extremely Pertinent!

If you have not read the brief report of Mr. J. R. Townsend, President of the American Society for Testing Materials, concerning the great difference he observed in German as compared to American manufacturing methods, you should read it. You will find it on Pages 44 and 45 of the October 1945 issue of the A.S.T.M. Bulletin.

By permission of that Society, we reproduce below most of one paragraph:

"The trend in American manufacture is toward the use of greater power, more automatic machinery, and a greater degree of mechanization of manufacture. This requires the production of an abundance of material of uniform dimensions and quality to be fed to this automatic machinery. It is only with such material that the automatic machines can work unattended and produce myriads of parts of identical form and quality. To control the uniformity of the raw material it is necessary to develop methods of test. It is also necessary to develop and adopt methods of inspection and quality control. The core of the matter is the development of tests that can be used to measure and indicate variability in quality. This has been the primary concern of A.S.T.M. and our principal contribution to the war effort has been the preparation of such tests and the embodiment of them with proper tolerances into specifications. The use of quantity production and quality control of materials has resulted in the production of an overwhelming amount of weapons that could be used in the war."

We are not now at war nor preparing for it, but methods of manufacture are identical for war and for industrial peacetime production. Germany used to be looked upon as the leader in use and manufacture of testing equipment. For the control of quality production in this country, over 13,000 "ROCKWELL" Testers were purchased between Pearl Harbor and V-J Day.

Competition with Germany in armaments ceased when the war ended, but competition between American firms is starting now. Those firms who follow most closely the successful American manufacturing methods are sure to win in peacetime competition. Quality control can never lose its importance.

See the "ROCKWELL" Testers in Booth C-142 at the National Metal Exhibition.



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S-Curve for Ni-Cr-Mo Steel*

THE S-curve of a nickel-chromium-molybdenum steel (0.3% C, 0.4% Mn, 3.4% Ni, 1.3% Cr, 0.5% Mo) was determined by a dilatometric method after three austenitizing treatments: (1) 10 min. at 1560° F.; (2) 1 min. at 2190° F. in nitrogen, then cooled to 1560° F. and held 10 min.; (3) 10 min. at 2190° F. in aluminum powder, then cooled to 1560° F. and held 10 min. The steel was softened at 1100° F. for machining but no attempt was made prior to the austenitizing treatments to remove the heavily banded structure that is usually found in this steel in the rolled condition.

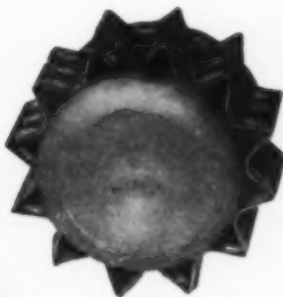
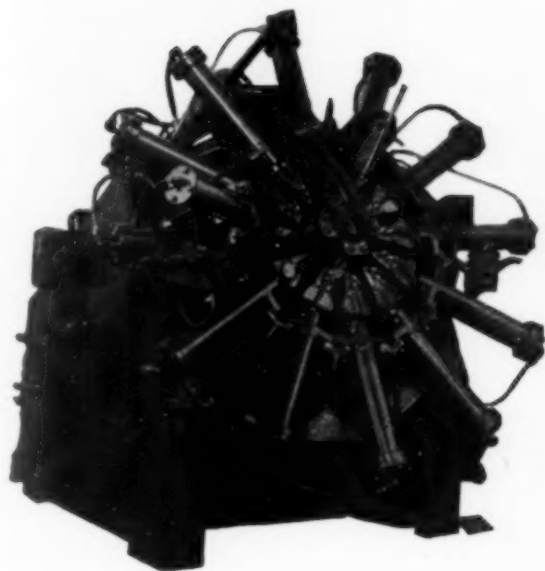
The 1560° F. austenitizing gave a typical S-curve with the fastest pearlite transformation at 1200° F. and the most rapid bainite transformation at about 705° F. The martensite transformation started at about 555° F., was some 90% complete at 210° F. and continued to increase slowly to room temperature. A small part of this transformation occurred at an increasingly slow rate at room temperature. Transformation as a whole was then probably very near completion.

Overheating at 2190° F. increased the grain size from 11 to 2 (A.S.T.M.). Both 2190° F. treatments gave the same results. The overheating retarded the pearlite transformation and rendered it much less complete (38% after 10 sec. versus 100% for the 1560° F. austenitizing). Contrary to the results of other investigators, the intermediate transformation was accelerated by the overheating and shifted to a slightly higher temperature (750° F.). The acceleration was partly reversed on retreatment at 1560° F.; this part of the change may be due to a change in grain size. However, in the main, this acceleration was a permanent change and was attributed to a redistribution of the carbon or alloying elements as the original banding was lessened by the overheating. Prior treatment at 2190° F. did not affect the transformation to martensite on continuous cooling.

(Continued on page 148)

*Abstracted from "The Effect of Overheating on the Transformation Characteristics of a Nickel-Chromium-Molybdenum Steel", by K. Winterton, Iron and Steel Institute Advance Copy, November 1944.

A HURRY!



FEDERAL RADIAL PROJECTION WELDER illustrates how odd shaped stampings of all kinds can be assembled with great economy and speed, by completing this eight-inch-diameter cooling fin assembly, 48 projection welds at once, in ten seconds.

FEDERAL MULTIPLE SPOT WELDER speeds stove production by welding this oven liner (on four sides at once) into a sturdy, economical sub-assembly.



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Important developments in equipment for automatically resistance welding aluminum, accelerated by critical war demands, are now being applied to the speeding of production in every branch of industry, from the making of household utensils and appliances to auto bodies parts, and accessories.

Difficulties encountered in welding aluminum alloys were due to the narrow "margin of safety" in their thermal response. The extreme accuracy of timing heat and pressure required were difficult to attain until perfection of the "stored energy" principle combined with full electronic controls.

The Federal Machine and Welder Company, perfected the first successful welders built specifically for aluminum. In collaboration with manufacturers of electronic controls, this company developed the Federal Unipulse System, in which a capacitor bank is charged (during comparatively long periods between welds) to a precise voltage level, then discharged directly into the welder as a single, uni-directional current pulse for production of the welds.

Among the important advantages of current Federal Aluminum Welders are . . . increased welding speed, higher quality welds, increased volume of production per cleaning of electrodes and lower KVA demands on the power line. Remarkable uniformity and high mechanical strength make it possible to design parts where stress may be involved with a full measure of exactness not possible with old methods.

"TEAMING" METALS BY WELDING

More and more combinations of metals of different characteristics are being teamed into single "product-units" for reasons of economy or greater workability, because of the ease with which such metals can be permanently united by resistance welding. Stainless steel is saved in the making of knives and tools by flash welding to mild steel shanks . . . heavy axe heads are made with most of their weight in low-cost steel, to which high grade hardenable cutting edges are welded . . . innumerable combinations are possible in radio and instrument manufacture, where perhaps a high conductivity must be combined with good spring qualities, not found in any one metal . . . stainless steel can be used for heads of large diesel engine valves and still have stems of steel best suited to stem wear. The Federal Machine and Welder Company designs and builds welders for all of these types of production . . . offers its engineering facilities to anyone with similar problems.

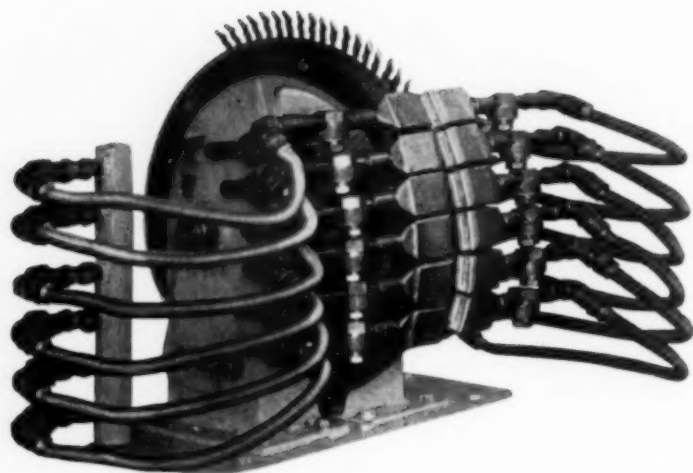
10 TO 20 SPOTS PER SECOND

For fabricators of metal who have production involving ten to several hundred fastenings on one plane a special type of automatic spot welder is available in which automatically operated electrodes are set up in multiples, much like a gang drill. Power demand is comparatively low, as electrodes weld one at a time in rapid sequence. For high production, machines may be had with electrodes in any desired pattern.

Called Ultra Speed Spot Welders, these machines are made by The Federal Machine and Welder Company. Descriptive literature available on request. "Bulletin 515".

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with advanced work-flow
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Other small parts can be hardened or drawn with equal ease. The next time you have such a problem in your plant, solve it with simplified work handling and function-fitted combustion—by Selas

Improved Heat Processing



SELAS CORPORATION OF AMERICA PHILA 34 PA

S-Curve for Ni-Cr-Mo Steel

(Continued from page 144)

When steel of this type is welded, a martensite zone is formed on either side of the weld. If the plates are restrained, stresses often cause severe cracking in this zone. Since these stresses are about one-fifth the normal strength of martensite, it was thought that this weakening might be caused by overheating in welding and that this might admit of dilatometric investigation. However, the present work showed that any weakening due to overheating is not accompanied by dilatometric changes.

Austenitic Weld Metal*

SHORT TIME, elevated temperature tensile tests, up to and including 925° F., were made on composite specimens taken at right angles to single run, 60° V, butt welds in alloy steel plate. The analyses of the plate, electrode and weld deposit are tabulated below:

	PLATE	ELEC-TRODE	WELD DEPOSIT
Carbon	0.32	0.06	0.14
Manganese	0.57	—	0.96
Silicon	0.22	—	0.35
Nickel	3.38	9.5	7.84
Chromium	0.65	20.0	14.24
Molybdenum	0.26	3.0	2.51

One set of welded specimens was softened at 750° F. to facilitate machining (without significantly affecting the properties). The other set was softened similarly and then treated at 1550° F. for 10 min.

Tensile and yield strengths decreased with increasing testing temperatures while the elongation was at a maximum at 480° F. The strengthening effect of the prior treatment at 1550° persisted for testing temperatures up to 300° F., and the loss of ductility persisted throughout the range of experiments.

Vickers hardness values were taken at room (Cont. on p. 150)

*Abstracted from "A Note on the Physical Properties of an Austenitic Weld-Metal and Its Structural Transformation on Straining", by K. Winter-ton, Iron and Steel Institute Advance Copy, November 1944.

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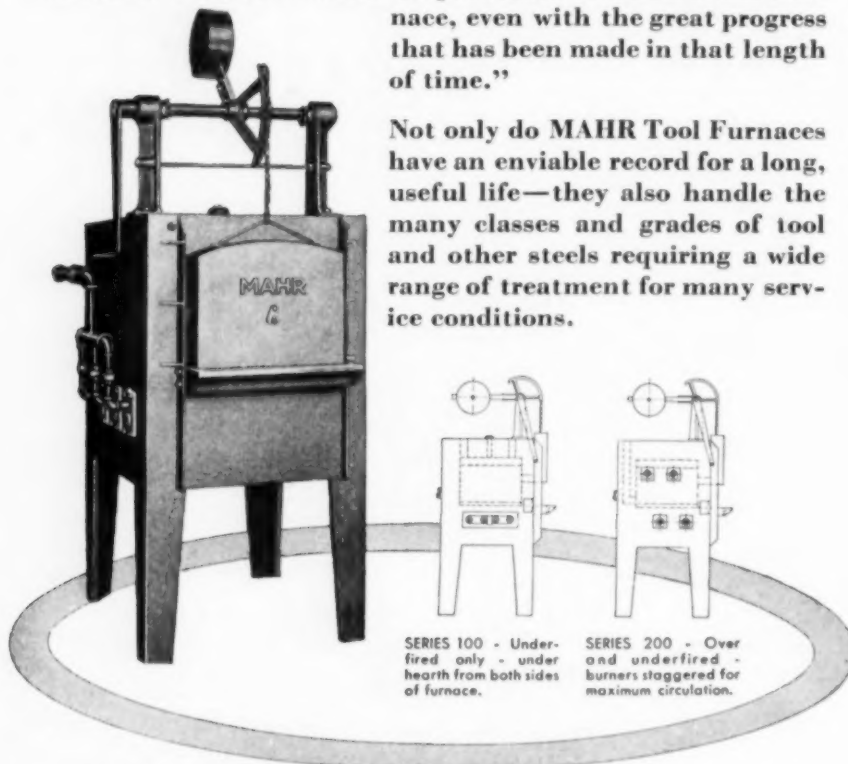
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Austenitic Weld Metal

(Cont. from p. 148) temperature on the weld metal near the fracture. The high hardness (450 to 500) decreased with increasing testing temperature to about 360 V.D.H. for 480° F. and thereafter remained fairly constant. All fractures were transcrystalline and occurred in the center of the weld except for two samples treated at 1550° F. and tested at room temperature and 125° F. These had an intercrystalline fracture which started at the weld interface.

Microscopic examination showed a change in the dendritic regions to a light-etching alpha constituent, and the formation of lines and blocks of a deep-etching alpha constituent, probably due to the uneven straining. The depth of etching of the light-etching alpha constituent increased near the fracture and with increased tensile testing temperature up to a maximum at 750° F. After treatment at 1550° F., the deep-etching alpha constituent was found at the grain boundaries, especially after testing in the range between 400 and 750° F. The presence of the alpha constituent at the grain boundaries of samples treated at 1550° F. accounts for their lower ductility. The high final hardness found after testing is attributed to the considerable lattice strain imposed by a close intermixing of the alpha and gamma lattices, rather than to the retention of carbon in supersaturated solution.

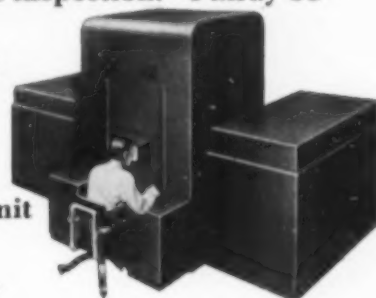
Heat Flow in Steel*

METHODS for the calculation of variable heat flow have been devised with the object of developing a general method of calculating the temperature distribution in a steel mass. The methods take into account the variable diffusivity of the material, latent heat of a change point and almost any surface conditions. Calculations made for a steel ingot cooling in a mold also allowed for the radiative heat transfer across the air gap between the ingot and mold and the different thermal properties of the two materials. Two instruments, one mechanical and (Cont. on p. 154)

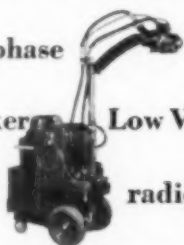
*Abstracted from "Variable Heat Flow in Steel", by R. Jackson, R. J. Sarjant, J. B. Wagstaff, N. R. Eyres, D. R. Hartree and J. Ingham, Iron and Steel Institute Advance Copy, July 1944.

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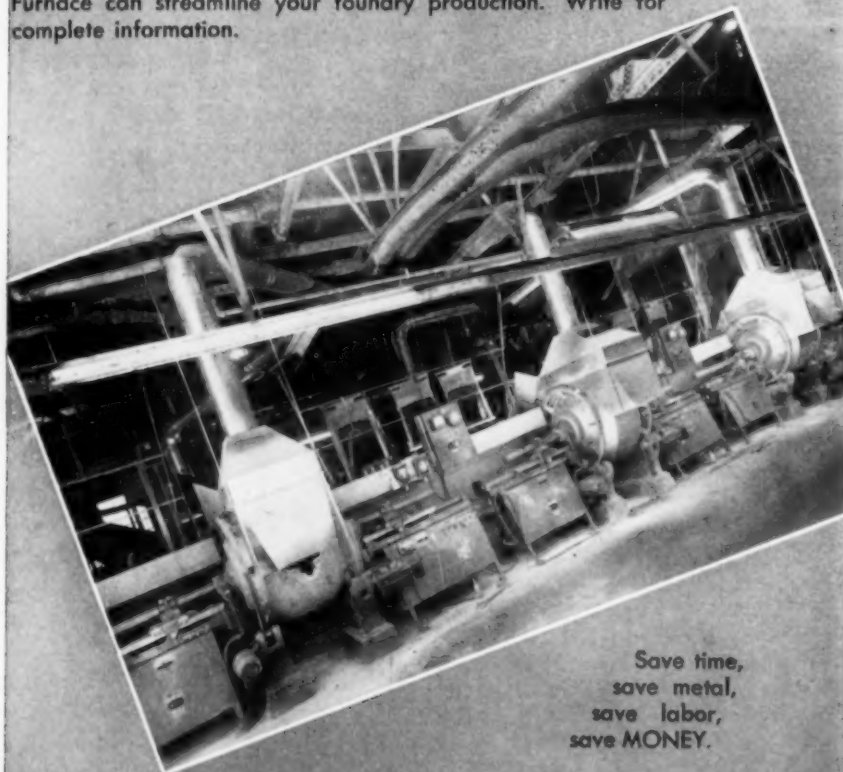
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Heat Flow in Steel

(Cont. from p. 150) the other electrical, have been used for the calculations, as well as numerical methods. The calculations show good agreement when compared with experimental results obtained both in the laboratory and on large-scale masses in industrial furnaces.

An interesting fact noted in the solidification of ingots is that the time taken for solidification was in every case less than the time for the mold to reach its maximum temperature. This suggests that up to the end of the solidification period, little of the heat released from the ingot had been transferred through the mold to the atmosphere, the greatest part still being held by the mold.

From a practical standpoint, it was found that the measurement of unsteady temperature, even when carried out by an accepted technique, can give erroneous results. These discrepancies did not become obvious until they were compared with a calculation.

It has been found that if the temperature throughout the steel is not near a change point and if the thermal properties depend on the temperature only and not on the thermal history of the material, the internal temperature distribution at any time depends to a considerable degree only on the surface temperature during an immediately previous period. Earlier stages in the variation of the temperature distribution have little effect on the internal temperature distribution at this time or subsequently.

As the research progressed, it was found calculated soaking times were always shorter than those given in industrial practice. Although the steel virtually attained a steady temperature in a short time, uniformity within the mass would remain unsatisfactory until the furnace brickwork itself had reached a uniform state. This was found with comparatively small masses of steel in a large furnace; it is therefore reasonable to suppose that in common practice where the hearth is more completely covered, the conditions would be considerably worse. Consequently, the conclusion that in industrial furnaces in which a high throughput is required, steps must be taken to heat the hearth of the furnace as well as the crown, is of great practical importance.

(Continued on page 156)

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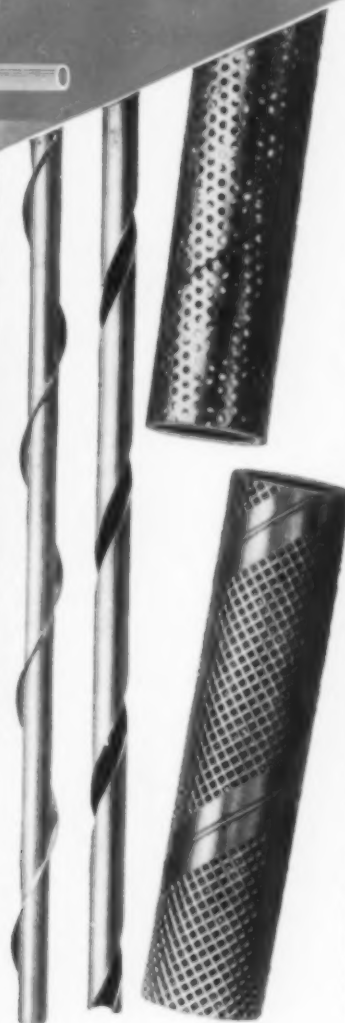


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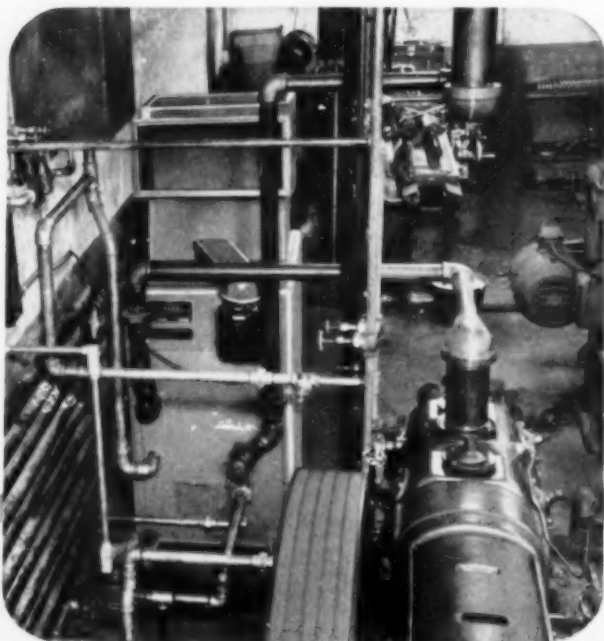
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Heat Flow in Steel

(Continued from page 154)

In many present furnaces, the so-called soaking time of the charge is in reality the soaking time of the furnace. Much greater attention must be paid to the method of heat input in designing furnaces. In the ideal furnace, the heat would be put in so that all parts of the furnace brickwork would act so as to supply heat to the charge at the same rate.

It is quite possible that all steels might be heated more rapidly than is commonly supposed if only the furnace temperature were raised uniformly throughout its mass during the heating. It may be that the lack of uniformity of temperature in the furnace is the real cause of clinking and that the temperature gradients in the steel mass itself would not be dangerous if only the steel were heated equally from all directions.

The soaking time is almost entirely dependent on four factors: (a) Properties of the steel being heated; (b) size of the mass; (c) the final part of the heating curve; and (d) the degree of uniformity required at the end of the soaking period. The relation between the soaking time and these variables can be represented approximately by a simple formula which could be evaluated by a nomograph or special slide rule. Therefore, the approximate soaking time needed in industrial practice can be calculated rapidly. It has become apparent that the soaking time is often more dependent on the furnace than it is on the steel itself. In such cases, the use of the nomograph will give misleading results as an indication of the temperature uniformity within the charge. The discrepancy between the calculated soaking time and the actual minimum soaking time found practicable in an existing furnace is a measure of the degree of improvement which may be achieved by modification of the furnace design. Finally, all the calculations are based on the true surface temperature whereas the temperature normally recorded is obtained by a sheathed couple placed somewhere in the furnace or at best resting on the stock. Even in the latter case, the difference may be easily as much as 90° F.

The method would be capable of wide extension if the necessary quantitative data on the thermal properties of steel were available. ☉



ONE PURPOSE OF METALS THE IMPROVEMENT BY FORGING

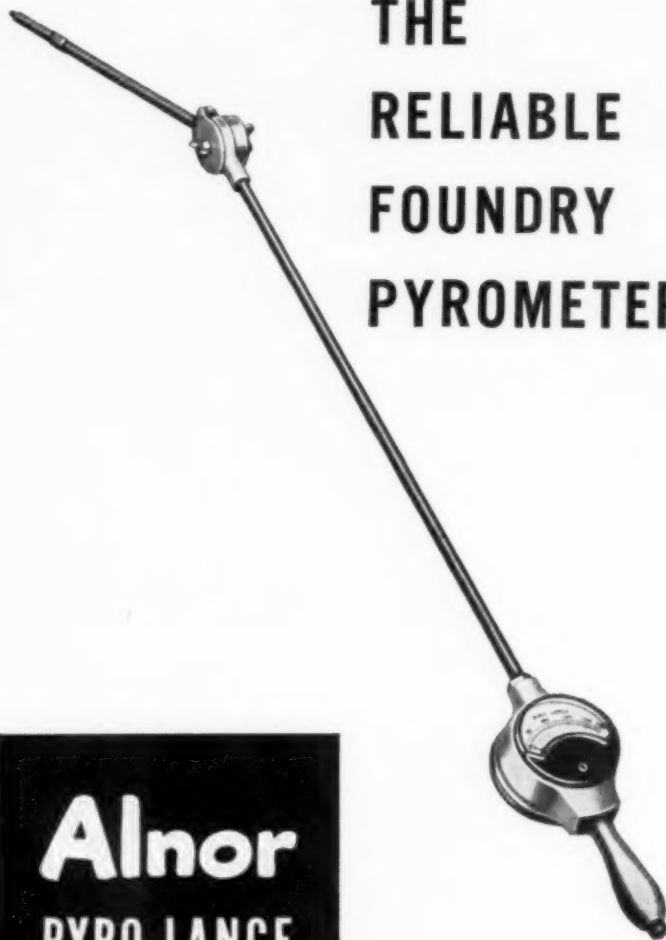
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Slow-Rusting Steels*

A NEW THEORY of the mechanism of rusting has been developed based on exposure tests started in 1941 on low alloy steels in industrial and marine atmospheres.

More sulphate was found in the rust from the industrial atmosphere and more chloride in the rust from the marine atmosphere. In general, the sulphate content of the outer rust increased with time, and the adherent rust had somewhat less sulphate than the outer rust. There was no indication that the copper and nickel in the alloy had accumulated in the rust; on the contrary, except at very low percentages, both nickel and copper had been lost from the outer loose rust.

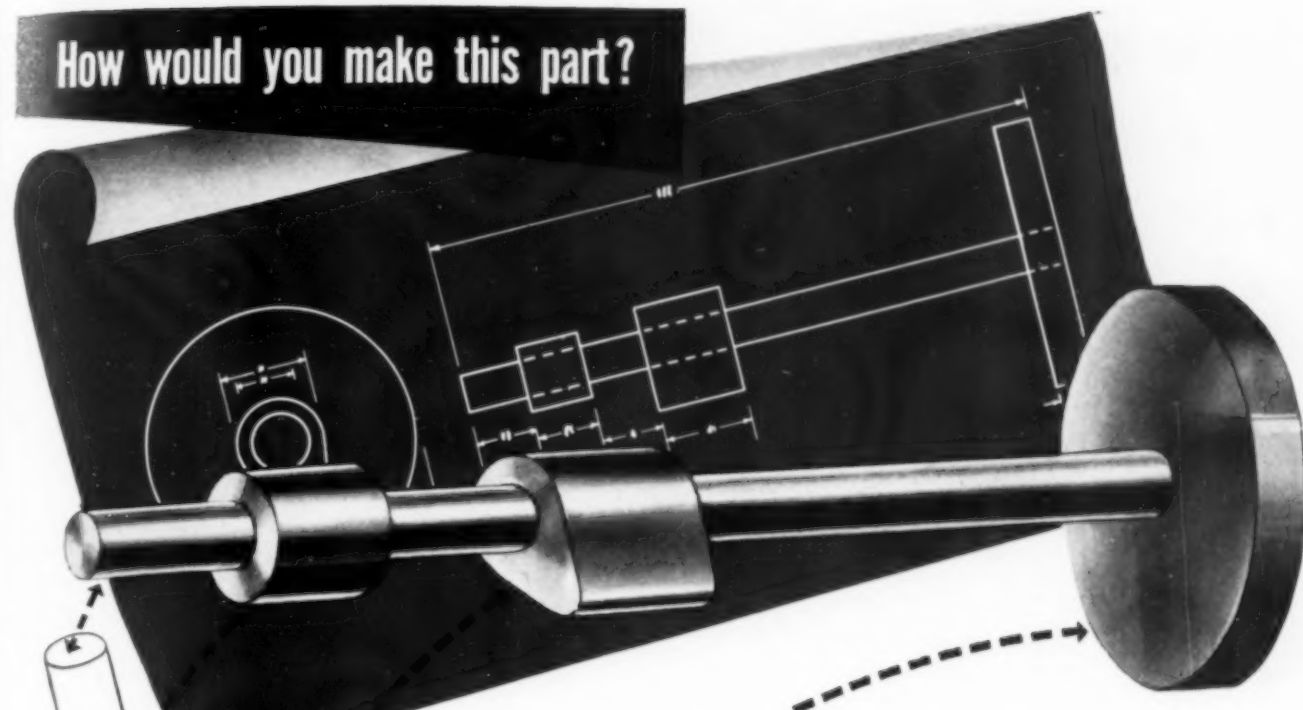
The rust from the groundward surfaces of the copper and nickel steels contained more moisture and sulphate than the rust from the skyward surfaces. This did not apply to ingot iron. The moisture content roughly paralleled the sulphate content. As the nickel content of the steel increased, the moisture and sulphate contents of the rust increased and the iron content decreased. The moisture and sulphate contents also increased with the increase in the copper content of the steel up to about 0.03% (and then remained relatively constant) while the iron in the rust decreased in reverse order. There is no doubt but that increased corrosion resistance is paralleled by increased sulphate in the rust.

Edge attack was much more severe in the marine than in the industrial location. The chlorides in the marine air were particularly effective in producing this type of attack. Corrosion was also more severe everywhere that salts collected. In general, edge attack decreased as the steels became more corrosion resistant (but this may have been simply a matter of small general weight loss). There was a better correlation between weather data and the edge corrosion than between weather data and weight loss. The amount of sulphur dioxide in the air seemed to be especially important in the so-called marine atmospheres.

On the basis of these results, it is postulated that the corrosion rate depends on the quality and quantity of water reaching (*Cont. on p. 168*)

*Abstracted from "A Theory of the Mechanism of Rusting of Low Alloy Steels in the Atmosphere", by H. R. Copson, American Society for Testing Materials, Preprint 25, 1945.

How would you make this part?



Do it faster and more economically with Lepel Induction Heating

This part could be machined from a solid bar — a costly and wasteful machining job.

— It could be made from a forging or casting, — necessitating expensive dies or patterns and entailing difficult and expensive machining.

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Surfaces to be joined are prefluxed and components assembled with the brazing alloy (preplaced in the form of rings) on the ground shaft. The assembly is positioned in a jig, heat is applied at sections to be brazed by means of properly-designed load coils and the brazing operation is completed in a few seconds.

As the heat is generated within the metal itself, the brazing alloy penetrates throughout the joint, producing maximum strength and soundness.

Accurate automatic control of time and temperature cycles prevents excessive heating, minimizing discoloration and practically eliminating surface scale. Little, if any, finishing is required. There is no waste of brazing alloy.

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January, 1946; Page 167

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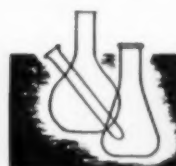
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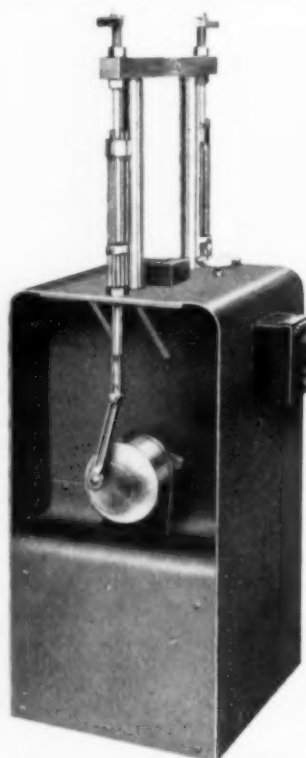
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Slow-Rusting Steels

(Cont. from p. 164) the steel surface. The quality is affected by atmospheric pollution, by the solubility of the corrosion products and by the washing of rains. Quantity is affected by the shelter and by the porosity of the rust, which in turn is affected by the solubility of the corrosion products. Relatively insoluble corrosion products decrease the amount of soluble constituents in the water and thereby decrease corrosion; they do not wash away; so they decrease the porosity of the oxidized coating and the quantity of the water reaching the unaffected steel. Rust on the corrosion resisting steels is least porous. Porosity of the rust decreases with time; as time goes on, pores become plugged and the resistance of the low alloy steels improves.

The function of copper and nickel is to render sulphates insoluble by forming complex basic sulphates. On mild steel, sulphates in the rust are relatively soluble and promote corrosion but are washed away by the rain. On alloy steels, the sulphates are less soluble so that corrosion is slower; however less sulphate is washed away and more accumulates in the rust. The percentage of sulphates in the rust therefore increases as the weight-loss decreases. At the marine location, severe corrosion of certain edges was due to the soluble chlorides being swept to these edges by the wash of the rain.

It seems significant that with the exception of phosphorus, all helpful elements such as chromium and manganese form insoluble basic salts and all neutral elements such as carbon and silicon do not. Furthermore, the only harmful element in steel from an atmospheric corrosion standpoint is sulphur, which upon corrosion would form sulphates and act in the same manner as atmospheric sulphur dioxide. Results are unpredictable when several elements are added at the same time, and it may be that the proposed mechanism does not tell the whole story. A review of the periodic system with the new mechanism in mind does not suggest any better alloy additions than those used today.

Variations in weather affect corrosion but may affect different steels differently. This is because rainfall has a dual role — moisture must be present (Cont. on p. 170)

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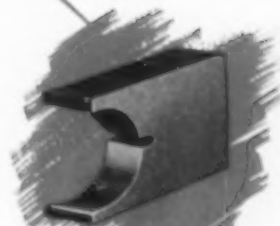
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10 TIMES LONGER!

Cutting soft aluminum sheets to special shapes rapidly dulled ordinary "tin" snips; left burrs on sheets. Carboley blades brazed to edges cut clean; lasted 21 days per grind.



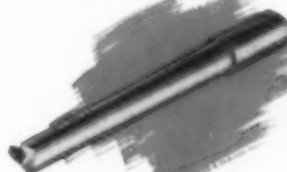
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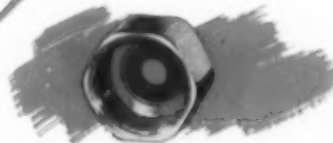
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Because Pangborn Special ROTOBLAST Machines (like the one illustrated above which cleans more than 250 blocks an hour) are the answer to faster and cleaner production at lower cost, they are being ordered by forward-looking manufacturers. One of the leading automobile manufacturers recently purchased five additional Special ROTOBLAST Machines to clean cylinder blocks, transmission cases, transmission housings, etc. . . . and a well-known farm implement company just ordered three Special ROTOBLAST machines. Both these companies have used ROTOBLAST equipment for years.

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* TRADEMARK OF THE PANGBORN CORPORATION

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PANGBORN CORPORATION • HAGERSTOWN, MD.

Slow-Rusting Steels

(Cont. from p. 168) for steels to corrode, but washing away of the soluble material is beneficial.

A factor that has been neglected is the composition of the film of electrolyte on the steel surface. It has been tacitly assumed in the past that in a given atmosphere each specimen is exposed to the same environment. Actually, owing to the influence of corrosion products, each specimen is exposed to a separate atmosphere.

Damage by Overstress*

TESTS were made on S.A.E. 1020 and a copper-manganese steel (0.3% C, 1.5% Mn, 0.5% Cu) to determine whether damage to endurance life at one series of loadings at a given overstress caused equal damage to endurance life when tested at a subsequent series of loadings at a lower (or higher) overstress. By overstress is meant a stress that is greater than the endurance limit as ordinarily determined.

S.A.E. 1020 was tested with an initial overstress 29% above the endurance limit for various cycle ratios ranging from 20 to 80% (that is, the ratio of the cycles of overstress actually imposed to the average normal life at that overstress). The final over stresses at which damage was determined were 25, 20, 15, 10 and 5%. The copper-manganese steel was tested with the following combinations of overstress: 30% overstress on the initial run plus 10% overstress on the final run; 30% + 20%; and 20% + 10%.

A series of high initial over stresses for a given cycle ratio followed by a second series of loadings at a lower overstress generally showed that the percentage of damage to endurance life at the higher stress caused a greater percentage of damage to endurance life at the lower stress. This damage to endurance life (measured in cycles to failure) may be four times greater at the final than at the initial stress. However, when the final overstress was close to the initial overstress, the damage was only slightly greater at the final than it was at the initial overstress. But the greater the differ- (Cont. on p. 172)

* Abstracted from "The Effect of Overstress in Fatigue on the Endurance Life of Steel", by J. B. Kommers, American Society for Testing Materials, Preprint No. 23, 1945.

DIE STEELS FOR COLD WORK



*

Colonial 6—Non-Shrinkable

For die applications where size and shape must be maintained closely, without grinding after heat treatment. Oil hardening, manganese types.

Red Star Tungsten

Oil or water hardening to a very high degree, combined with excellent toughness and wear resistance. Tungsten, chromium, vanadium and molybdenum alloy.

Air Hard

For intricate dies, with very low movement when air cooled. Easily machined when annealed—no cracking tendency in hardening. Chromium-molybdenum type.

Crocar

High carbon, high chromium alloy; highly wear-resistant when heat-treated, yet readily machined in annealed condition. Oil hardening.

Ohio Die

Closely related to Crocar, but air hardening, with slightly lower carbon content, and high toughness values. Low movement in hardening.

Colonial 4

A water hardening tungsten steel capable of intense hardness and wear resistance. Ideal where hard case and tough core are required.

All of the above steels are available in shafts, bars, cold drawn shapes, solid forgings, ring forgings, sheet, plate, circles, and drill rod.

Vanadium-Alloys

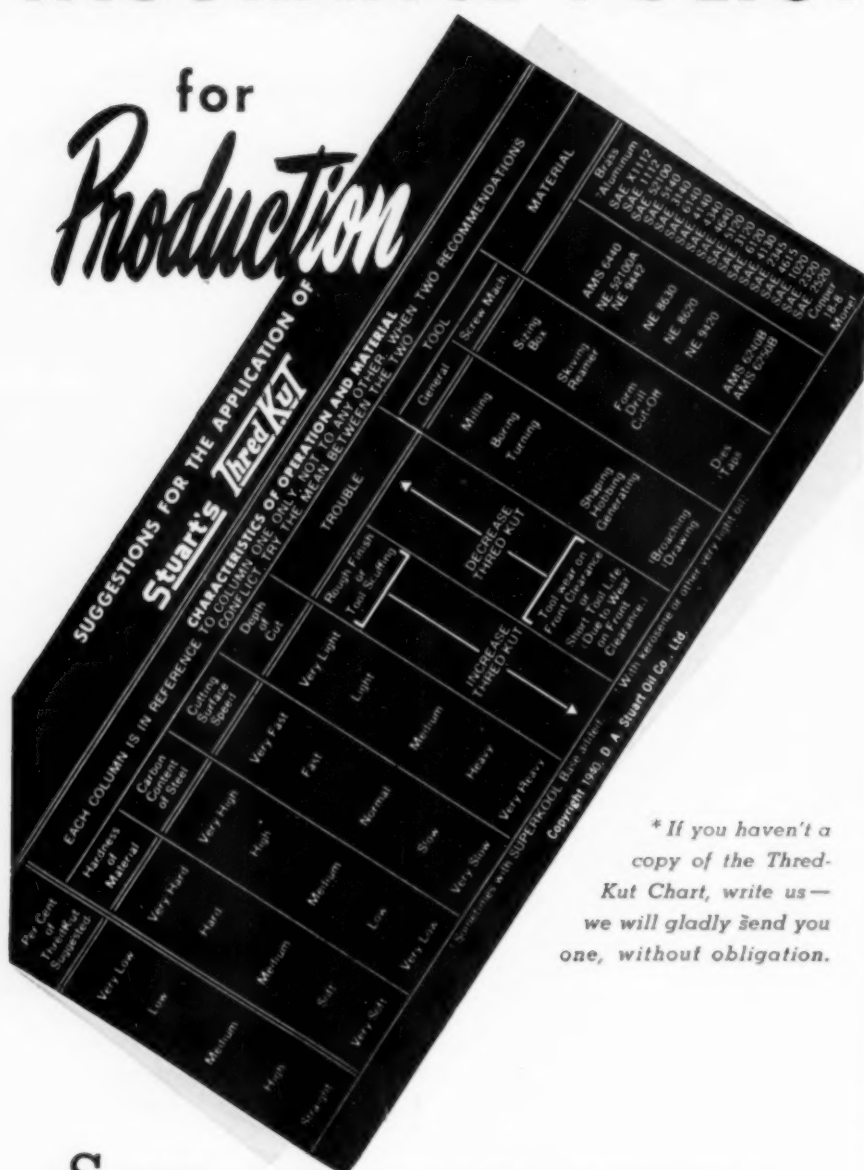
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Damage by Overstress

(Cont. from p. 170) ence between the initial and final over stresses, the greater was the damage.

The damage as measured by the decrease of endurance limit was much less than the damage measured by the decrease of endurance life.

Similar tests were made with the final overstress *higher* than the initial overstress. S.A.E. 1020 was tested with an initial overstress of 5%, cycle ratios of 20 to 80%, and final over stresses of 10, 15, 20 and 25%. The copper-manganese steel was tested with 10% initial overstress + 30% final; 20% initial + 30% final, and 10% initial + 20% final. In general, the percentage damage to endurance life at the lower stress caused a smaller percentage of damage to the endurance life at the higher stress. Low initial overstress for small initial stresses and lower cycle ratios may even produce an actual increase of over 100% in the normal endurance life at a subsequent higher stress.

The indications are that the harder, stronger steels, such as the copper-manganese steel, are more sensitive to damage by overstress (as far as the endurance life is concerned) than the softer weaker steels, such as S.A.E. 1020. 

Gage for Surface Finish*

A MACHINE for measuring surface finish, the "Topograph", has been developed by David Brown and Sons of Huddersfield, England. It operates on a simple pneumatic principle; no electrical apparatus is required, but only a supply of compressed air at any pressure between 35 and 90 psi.

A pen record on a 5 by 10-in. card is made in 3 min. This record is an enlarged profile of the surface irregularities along a selected straight line as picked up by a diamond tracer. Curved surfaces may also be measured if these contain a straight element, such as the surface of a shaft or bore along a straight line parallel to the axis. Records can also be taken on bored surfaces at distances up to 6 in. from the mouth of the bore if the diameter is not less than 1 in., and up to $\frac{3}{8}$ in. from (Cont. on p. 176)

★Abstracted from "The 'Topograph' Surface Finish Measuring Instrument", *Engineering*, June 1, 1945, p. 427.

Making Wedge Wire Screens of Stainless Steel

Fabrication of Special Screens for Industrial Purposes Requires Stainless that is Uniform and Will Stand Severe Deformation - both Hot and Cold

Given a stainless steel which is completely uniform—the kind that the Rustless Iron and Steel Corporation makes—and an adequate amount of sales engineering, a comparatively small company can fabricate "difficult" products of stainless steel with less trouble than is encountered with most other materials. This is the experience of Wedge Wire Corporation of Cleveland, Ohio, makers of special screens for coal washing and for foods and chemicals.

Machinery for making Wedge Wire screening was brought to this country from England only a few years ago. The unique product made with this equipment is attracting wide interest because of several advantages over ordinary wire mesh claimed for certain applications. The screen-wire itself is formed into wedge or other shapes (see next page) to produce controlled openings through which the liquid and

screening, Wedge Wire screens are more rigid than ordinary fine mesh.

Wedge Wire screens must be made to close tolerances. To achieve a high degree of control of screening the wire-to-wire openings must be held to plus or minus .002", which means holding the top widths of the wires themselves to plus or minus .001".

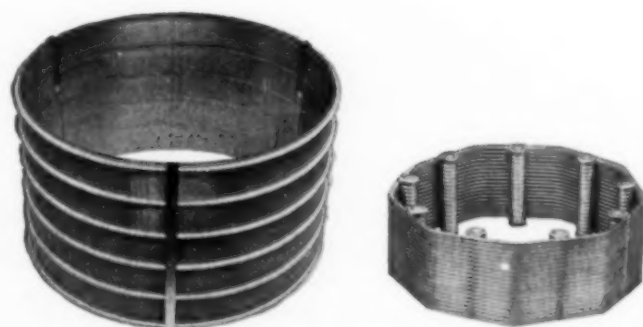
The assembly of the screen calls for forming loops at evenly spaced intervals in its wire members and passing tie-rods through the loops of several consecutive wires to form a screen which is rigid and in exact alignment. The loops must mate where the wires cross the tie-rods, to form tight and clog-proof joints. And the inside diameters of the loops must have a close but not binding fit on the tie-rods to form an assembly which is free from play between members but also is free from strain. All of this calls for stainless steels which will deform



they may be placed are in chutes, hoppers, shakers, sluices, drag conveyors and baskets in stationary or moving frames. They are also formed into circular sections for suction filters, centrifugal and rotary screens. While retaining their true form and stiffness under such service, the screens must handle products which may be erosive, corrosive, or both. Wedge Wire screens find wide use in coal, processing plants, chemical plants, food plants, soy-bean and other oil plants, limestone plants and the like. It is because of superior structural and fatigue strength as well as resistance to both erosion and corrosion that stainless steel is used. Stainless steel not only is longer-lived in service, but with its superior mechanical properties increases the kind and amount of stress to which the screens can be subjected and thereby widens their fields of usefulness.

Rustless 17 and 18-12-3Mo, stainless steel Types 430 and 316, are used; Type 430 is preferred for coal plants and Type 316 for chemical and food plants. The material is bought with a thin uniform electro-deposited copper coating, the copper acting as a die lubricant when forming the wires and loops. Generally the copper is not removed since it in no way affects either the performance or the durability of the screen. If it is necessary to remove the copper, this is easily done by dipping in a 10% solution of Nitric Acid. This dissolves the copper but does not affect the stainless.

Production operations include straightening the round wire which has been received in coils; cold forming the loops and cold pressing into the wedge cross section or other shaped members, cold heading one end of each tie-rod, passing the tie-rods through the loops for preliminary assembly, squeezing the wires together along the tie-rods to get the final tight and rigid assembly,

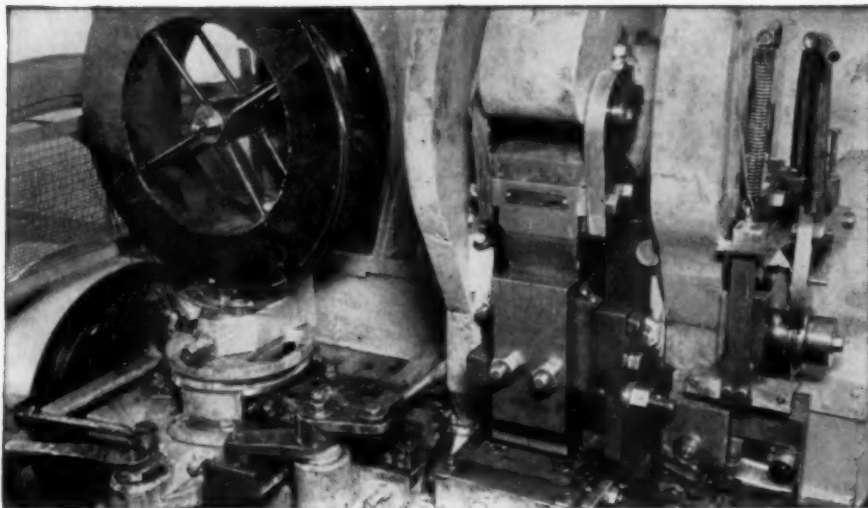


Two Types of Stainless Steel Wedge Wire Circular Screens.

finer being screened can pass. The fact that the surface is almost flat is one reason why Wedge Wire is less apt to clog and thus gives greater production than ordinary screen. The flared contour of the escape passage is also said to produce a desirable orifice and minimize clogging. Furthermore, of fine

to exact tolerances under the dies which form the wire and loop shapes, and which will not spring back or creep appreciably after being deformed.

In service the screens are for de-watering, filtering, washing, drying and the separation of materials. A few of the numerous places where



The working Area of the Forming Machine.



Cold heading on a Conventional Type Riveter.

cutting off the tie-rods to length, and hot heading the open end of the tie-rods to hold the wires in place.

Stainless steel shows definite advantages at the first or straightening operation. Straightening is done in a conventional double bending machine, with the wire being wound on special reels to fit the forming machine after the wire has been straightened. One of the purposes of straightening is to take the kinks out of the wire which resulted from possible rough handling in shipment. Once out of stainless these bends do not return as they sometimes do in other metals of which these screens can be made. That is, the proper kind and temper of stainless steel is more readily straightened, and does not spring back. This reduces fabricating costs, since bends in the wire result in stoppages at the forming machine and sometimes in broken dies.

The forming machine loops the wire, forms its cross sections to true and accurate contours, and cuts it to the length needed for the screen, all by fully automatic operations.

The first operation in this machine is forming the loop by winding the wire once around a die pin. Here the complete uniformity of Rustless stainless steel first shows its value. If all of the shipments of wire passing through this process were not alike in both size and temper, then some loops would bind too tightly on the pin so the pin could not be withdrawn to clear them, some would wind too loosely and result in oversize loops which would need special diameter tie-rods for assembly, and some might spring back after winding so that subsequent forming operations would be

impossible. With Rustless stainless steel there never is any trouble.

The round wire with loops in place passes to the forming dies. This forming operation is severe. It must produce flat surfaces, concave ones, or convex ones which possess two entirely different radii than those of the original wire, hold one or more dimensions to plus or minus .001", and deform the wire through about one-third of its original cross-sectional area. The loops also must receive new cross-sectional forms, and these are different from those of the straight sections of the wire. The fact that all this can be done on machines which have only ordinary press actions and which use dies made of ordinary die steels, should relieve many a metal fabricator of the idea the stainless steels are necessarily difficult to work.

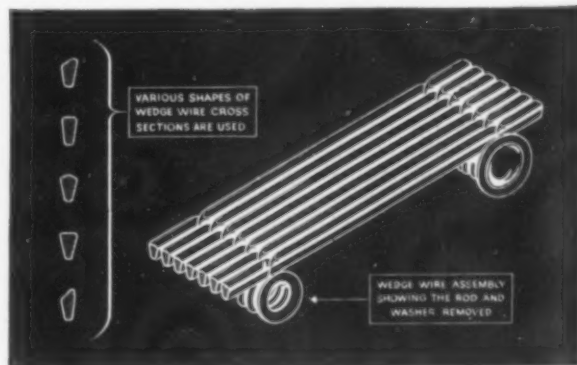
Severe forming operations like these cause the metal to flow lengthwise as well as crosswise of the wire. This lengthens the distances between the already spaced and formed loops. Here the complete uniformity of Rustless stainless steel wire provides a second advantage.

Any lack of uniformity in the wire will change the distances which these loops move apart under the forming. Resetting of the machine motions can compensate for some variations in the loop spacings, but any such variations result in increased or decreased over-all lengths of the finished wires since

the automatic cut-off mechanism is actuated by a counting mechanism which trips the cut-off after a preset number of strokes of the forming ram and not by anything which takes lineal measurements. The finished wires must come to correct lengths or (if not too bad) be cut to length or else be rejected. Any corrective operations whatever mean loss of machine time and of labor time as well as scrapping materials upon which expensive operations have been performed. With uniform Rustless Stainless Steels these troubles are not encountered.

Completely uniform materials also are important at the cut-off. A steel that is too hard will snap off under the cut-off tool, this tendency being enhanced by the amount of work hardening which the material can receive under the previous severe forming. A material too soft can mush or deform here. Either condition requires a corrective operation if the finished wire is to be salvaged. Completely uniform and correct material avoids this added expense.

Finished Wedge wires run automatically into a gutter of a flat,



metal-topped table. They are transferred to the table top, their loops are aligned, and just enough steel assembly guide pins to hold the wires in alignment are run through a few rows of the loops. Then the wires are transferred to the assembly department.

Primary operation of assembly is to cut stainless steel tie-rods into lengths a few inches longer than the intended widths of the finished screens. This is done in an ordinary power hack saw.

One end of each piece is cold upset to form a head against which the wire loops can bear. This upsetting is done with an ordinary air hammer or in a conventional-type rivet-spinning machine. This company never has had any trouble with upsetting operations on Rustless Stainless Steels.

The Wedge Wire loops are held to close but not extremely fine tolerances. Originally they were held to plus or minus .0015"; an over-all tolerance of .003". But when experience proved that the inside diameters of the loops were more likely to come undersize than oversize, due to wear reducing size of the winding pin, the tie-rod dimensions were changed to plus .000" minus .003", thus bringing all of the tolerance to the minus side.

The fit of the loops on the tie-rods ranges from snug to light press categories, but never a force fit or a drive fit since the loops are desired to be supported but not strained and not to be given any tendency to cock or to deform during the assembly operations. The rods, then, are inserted by hand, the assembly guide pins which had been inserted at the forming machine being withdrawn.

The loose assembly is moved over so the cold-headed rod ends bear

against a raised edge of the assembly table. This raised edge is to serve as one jaw of a clamp. The opposite jaw is placed against the free side of the assembly and is tightened toward the raised edge of the table. Tightening the loops together leaves an excess end of tie-rod protruding from the side. This is cut off, an adaptation of a conventional portable pneumatic shear being used for the purpose. Complete uniformity of the rod stock is important to this operation to avoid deformation of the rod ends.

Enough of the excess end is left for final hot upsetting. A stainless-steel washer is placed on this end; the end is quickly raised to red heat with an acetylene flame, and the final hot upsetting is done with a portable compressed-air hammer of conventional type. Rapid air cooling is not detrimental to Types 430 or 316 for Wedge Wire applications.

A variation of this assembly procedure is used when the screen is to be curved to be used in a centrifugal or other machine. The "top" surface of the screen can be arranged for the screened material to pass either from the outside to the inside or from the inside to the outside of the screen cylinder. In either case, it is the tie-rods and not the screen wires which must be bent. The bending is done before assembly, the rod-end usually being threaded so that nuts can hold the meeting edges of the screen to a joining member (usually a channel iron) which completes the wall of the cylinder.

A still later variation is to make the screen flat and then curve the rods in a bending brake. Mechanical techniques for this are being developed by a user of the screens but are being kept unpublicized. By such methods the finished screens can be

treated as semi-finished raw materials to be formed into many special shapes for better adaptation to special purposes.

The Wedge Wire Corporation and its customers, then, are able to severely deform and re-deform stainless steels with no special or extra careful handling, no heat-treatments of any kind, no metal cleaning or other "after processes" to prevent corrosion, and almost no manufacturing rejects. They are doing no more than handle it in the offhand manner that would be accorded to "ordinary" metals. They are handling it in a trouble-free way that is made possible first by the excellent fabrication and mechanical properties of stainless steel in general, and second by the complete uniformities of Rustless Stainless Steels. And of all the factors which permit this simplicity of methods, uniformity is by far the most important.

The End.

Rustless engineers are glad to work closely with those who fabricate stainless steels into industrial equipment or consumer goods. Their cooperation has been invaluable to many firms, which is natural enough since Rustless has never done anything in its entire history except produce, study, learn about stainless, how to machine, forge, heat treat, electropolish, blacken, otherwise work with stainless easily and economically. Much of the Rustless knowledge has been put into printed form. Write for helpful new chart entitled "Trade Names of Stainless Steels."



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"Falls Brand" Alloys

Falls 50-50 Copper Nickel

FALLS 50-50 Copper Nickel has a lower melting point than pure nickel that melts at 2646° F. and is more soluble than pure nickel. It is, therefore, within the range of the average brass furnace and its introduction is possible without overheating the alloy. Its principal advantages are:

**Increased production
Reduced fuel consumption
Increased life of crucibles and furnace linings
Less rejected castings produced**

And most important:

A Saving in Production Cost

Introduced at the beginning of a heat, it will be molten when the rest of the charge is liquid.

Used for the introduction of the definite amounts of nickel in making nickel base alloys. Used for "holding up" lead in high lead alloys.

"FALLS" 50-50 COPPER NICKEL

Produced in Shot Form

NIAGARA FALLS SMELTING & REFINING CORPORATION

America's Largest Producers of Alloys

BUFFALO 17, NEW YORK

Gage for Surface Finish

(Cont. from p. 172) the mouth of bores with diameters from $\frac{3}{8}$ to 1 in.

Heights of the surface irregularities are ascertained directly from the graph by multiplying by the particular conversion factor for which the machine is set. The ratio of the pen movement to the tracer point movement may be adjusted between 5000 and 20,000 to 1; that is, a pen movement of 0.1 in. corresponds to a roughness depth between 5 and 20 micro-in., according to the instrument setting. A surface irregularity of 2 micro-in. can be readily detected with a magnification ratio of 20,000 to 1.

The record is unaffected by any change of speed below 0.033 in. per min. The response is uniform for all surface wave lengths greater than about 0.0005 in. Therefore, on any surface likely to be encountered, the irregularities on all wave lengths are reproduced uniformly. The part to be measured should weigh under 100 lb. and be not deeper than 18 in. Larger parts can be measured by removing the tracer head and supporting it in a suitable position above the surface. The only limitation is imposed by the length of the flexible connection between the tracer head and the instrument cabinet. One condition is that the surface to be examined must be horizontal or at least approximately so.

Corrosion Fatigue of Lead*

FATIGUE of pure lead, tellurium lead, 1% antimonial lead and commercial storage battery lead (9% Sb) was determined in a rotating beam, cantilever-type machine at 1785 r.p.m. It was found necessary to "over-age" the lead alloys (48 hr. at 320° F.) to get reproducible results. However, this does not simulate the room temperature aging experienced by commercial battery grids. Although electrolytic polishing gave a scratch-free surface, mechanical polishing had to be used, since specimens electrolytically polished as the final step lost all resistance to fatigue. The following endurance limits were obtained: (Continued on p. 180)

*Abstracted from "The Corrosion Fatigue Properties of Some Hard Lead Alloys in Sulphuric Acid", by David J. Mack, American Society for Testing Materials, Preprint No. 32, 1945.

36

PERMITE ALUMINUM CASTINGS



Contributed to the Precision of the NORDEN BOMBSIGHT

THAT the deadly accuracy of American Bombers, made possible by the Norden Bombsight, was a big factor in ending World War II is universally admitted. Naturally an instrument capable of such pin point accuracy as the Norden Bombsight must be made of only the most precisely engineered and fitted parts. The fact that 36 of these parts were Permite Permanent Mold Aluminum Castings bears high testimony to the accurate dimensions and uniform quality of Permite Castings.

The qualities of strength combined with light weight, resistance to corrosion and easy machinability, inherent in Permite Aluminum Alloy Castings, will prove equally valuable to your peacetime products as to the Norden Bombsight and so many other wartime implements.



When you use Permite Aluminum Castings it means that you get castings of superior physical and dimensional quality, as a result of strict specification adherence and critical supervision and inspection. Standardization of technique and modern laboratory control, supported by X-ray inspection and spectrographic analysis, further guarantee correct physical qualities.

Let us show you what Permite can do in meeting your castings requirements. Recommendations made without obligation.

ALUMINUM INDUSTRIES, Inc. - CINCINNATI 25, OHIO

Detroit: 809 New Center Bldg.

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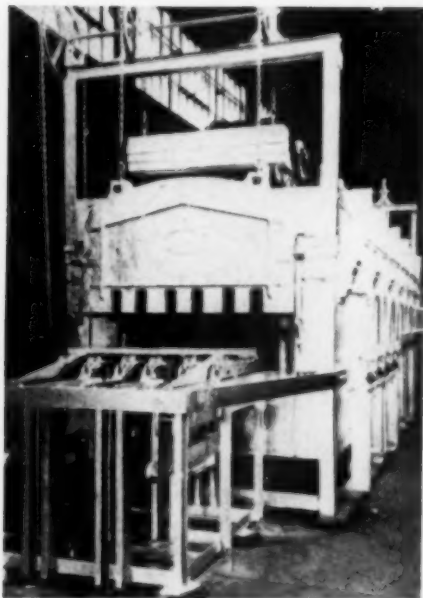


PERMITE ALUMINUM ALLOY CASTINGS

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● In the construction of Bellevue Furnaces, painstaking consideration of the job to be done comes first. Every factor must be evaluated, every condition studied. Only then do Bellevue engineers attempt design and recommendation of furnace type.

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Send for full details.

**BELLEVUE
INDUSTRIAL
FURNACE CO.**

2980 Bellevue Ave.

Detroit, Mich.

Corrosion Fatigue of Lead

(Continued from page 176)

	IN 38% IN AIR H ₂ SO ₄	IN AIR* (CORRODED)
Pure lead	430 psi.	0
Tellurium lead	600	400 psi. 1300
1% Antimonial lead	860	740 1200
Storage battery lead	2050	1850 2050

*Specimens previously corroded in sulphuric acid while stress-free.

The results show that simultaneous corrosion and cyclic stress cause serious damage. Hence, corrosion fatigue is probably one of the variables preventing the correlation of laboratory and service tests on battery cells. From the results on the commercial storage battery lead, it is possible to deduce the properties an alloy must have to be used successfully as a grid material in a storage battery:

1. Ability to be cast into intricate grids in an automatic machine.
2. Castability and formability so the active material may be pasted into the grids.

3. A fatigue limit in air of at least 1500 psi. with a corrosion fatigue in battery acid at least 75% of the limit in air.

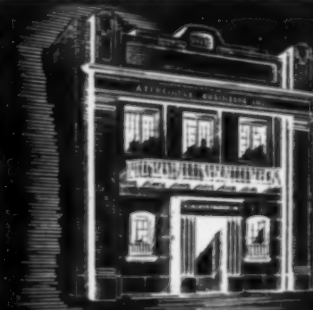
4. An adequate corrosion resistance, so the battery acid will not be contaminated by material from the grids, thus causing a short life.

In corrosion fatigue it is believed that the normally protective lead sulphate film is damaged in two ways by cyclic stress; either its adherence is affected by the tendency of lead to recrystallize during stressing, or the cyclic stresses open up cracks in the protective film. This allows the acid to attack the grain boundary, creating a notch.

Rapid Quenching of Aluminum*

THE SOLUTION TREATMENT of aluminum alloys is generally done in a salt bath or air oven. The salt baths give a more uniform temperature. While the temperature of the air ovens cannot be controlled as easily, (Cont. on p. 182)

*Abstracted from "Tank Quenching of Heat Treated Aluminum", *Western Machinery & Steel World*, July 1945, p. 322.



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Our services provide the combined talents of registered licensed, professional industrial and mechanical engineers, accountants, architects, structural, civil and hydraulic engineers, electrical, heating, ventilating, air conditioning, chemical, foundry and metallurgical engineers to work closely with members of your staff in helping to build a more effective business organization.

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The Most Efficient and Economical System for Induction Heating

Announcing MODEL "1400"

The Newest, Largest and
Most Versatile of Induction
Heating's Growing Line of
THERMONIC

High Frequency Electronic Generators

Some of the features incorporated in Model "1400" are:

INPUT . . . 220 Volts, 3 Phase, 60 Cycle, 48 KVA at 90% Power Factor.

OUTPUT . . . 1400 BTU's per minute or approximately 25 KW's at a frequency of 375,000 cycles per second. Variable output optional. A single dial permits the output of the generator to be controlled from zero to full load.

THREE PHASE SUPPLY . . . The power supply section of the unit contains a 3-phase full wave power supply which operates at 90% power factor.

2800 BTU OUTPUT . . . By operating two Model "1400" THERMONIC Induction Generators in a tandem set-up, an output of 2800 BTU's per minute or approximately 50 KW is available.

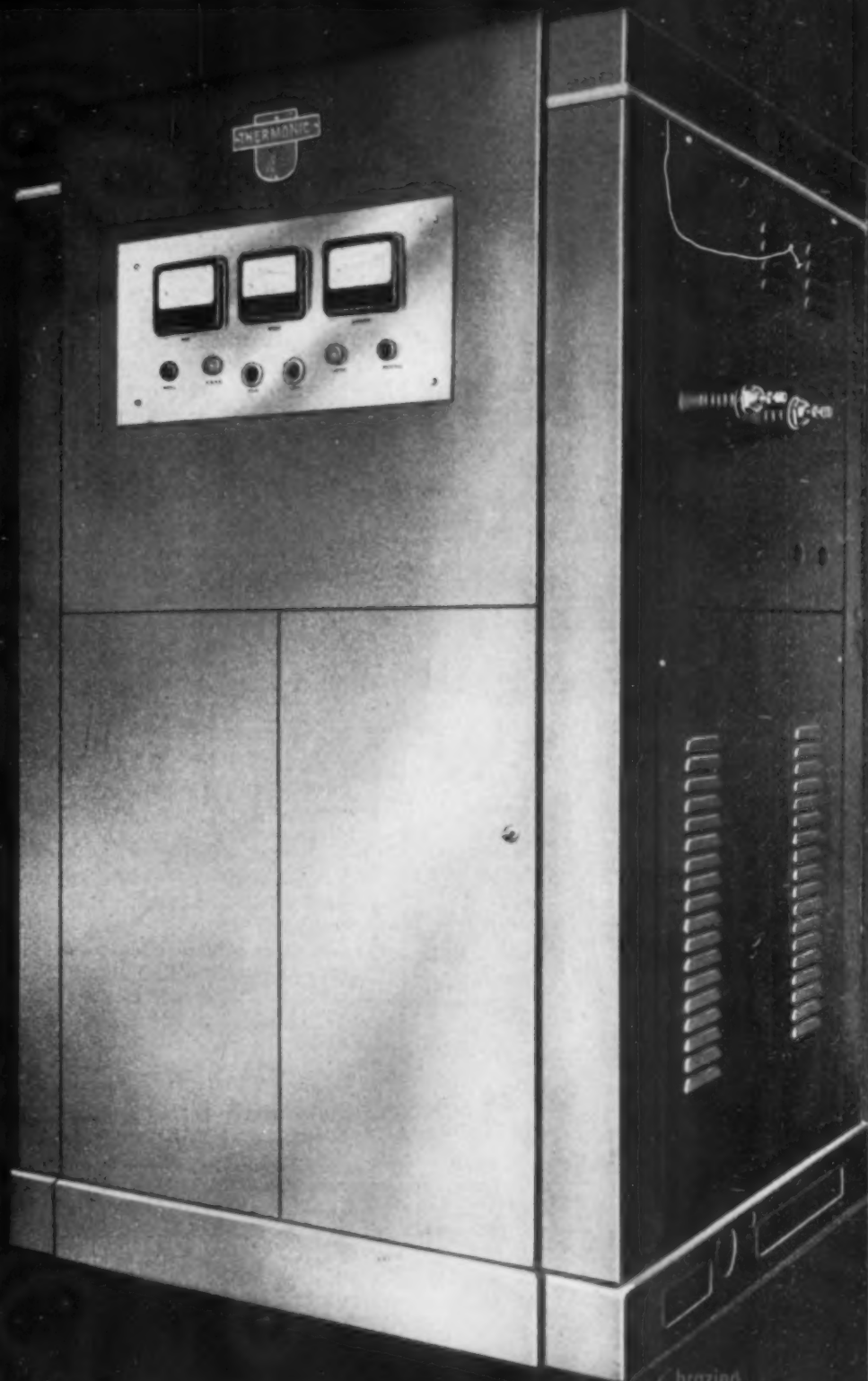
FILAMENT VOLTAGE CONTROL . . . The unit includes an automatic voltage control which regulates all filament voltages to a pre-determined value independent of line voltage changes.

TIME DELAY WATER SYSTEM . . . Incorporated in the unit, there is a new patented time delay water system. This device makes it impossible to damage the tubes by turning off the water too soon after the generator has been shut down.

SUPERVISORY CONTROL . . . The instrument panel contains pilot lights which give supervisory control on the overload relay and water system.

DIMENSIONS . . . 43" wide, 39" deep, 72½" overall height. Weight, approximately 2,000 lbs.

This new unit greatly increases the potentialities of induction heating. The members of our technical staff, therefor, now welcome the opportunity to give you the complete details. Inquiries invited!



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NEW YORK

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Largest Producers of Electronic Heat Treating Equipment for

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melting
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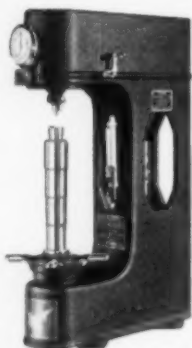
Gives Continued Accuracy, Rapid Measurements

THE CLARK has everything you want in a hardness tester—direct reading precision dial, durable construction, ease of servicing. Three standard models shipped complete with weights, dust protectors, diamond and steel penetrators, test blocks, and anvils.

CLARKATOR CHECKS DIAL INDICATORS with micrometer speed and sine bar accuracy. Easy to operate—just four simple steps. Complete instructions, permanently fastened to base.

MASTER DIAMOND CHECKING SET eliminates hardness tester errors. Consists of a master diamond penetrator and two test blocks. Precision is assured over a long period because the set is used only for checking. Furnished in leather case.

Learn the truth about hardness testing! This 20-page reference manual (right) contains information on history, theory, practice, and equipment for modern hardness testing. Available to executives without charge. Write Dept. MMS today!



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MASTER DIAMOND CHECKING SET

CLARKATOR CHECKS DIAL INDICATORS

CLARK
INSTRUMENT, INC.

10200 Ford Road • Dearborn, Mich.

Quenching of Aluminum

(Cont. from p. 180) they produce less distortion on formed parts and can easily be adapted for mechanical loading; moreover, there is no danger of burns from molten salt.

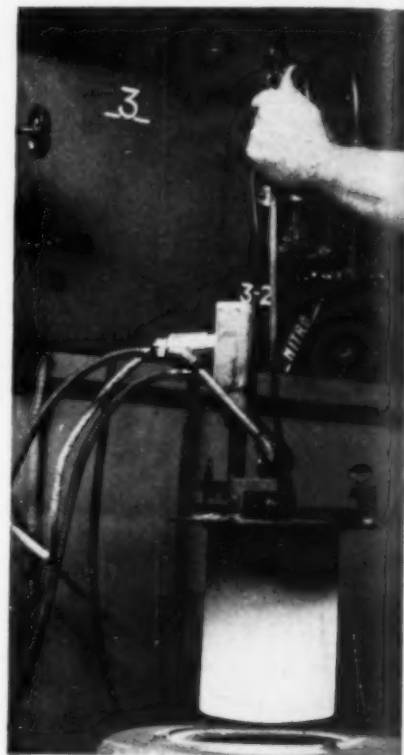
After aluminum parts have been heated by either means, they must be quenched to room temperature within 8 sec. to retain the hardening constituents in the solid solution. The formerly used method of spray quenching gave erratic results; quenching in a cold water tank has been found to be much better. Hand quenching of small parts is particularly adaptable to salt baths but is very inconvenient for air furnaces; it also limits the capacity of the equipment. Many bottom-dump air furnaces are slow, inconvenient and inefficient; this can only be corrected by careful design.

In air furnaces at Douglas Aircraft Co. the atmosphere is circulated vigorously and gives a uniform furnace temperature within $\pm 3^\circ$ F. A water tank is installed in a pit directly in front of the furnace with its upper rim approximately level with the furnace floor. A quenching machine has been developed which eliminates most of the inherent drawbacks.

Parts are loaded on a light rack of chromium-molybdenum steel tubing. Life of these racks is six to nine months. A carriage is provided to support the rack while loading and unloading. There is a device for supporting the rack over the tank, while charging the oven and later while plunging the rack into the tank. A pull on a hook rolls the loaded rack out of the oven into the quenching mechanism; in its movement the rack engages a trigger valve which releases the air from an overhead cylinder and allows the mechanism to move forward and downward, plunging the loaded rack into the water tank.

Normally 200 to 300 lb. of aluminum parts constitutes one load. Eight loads per shift per oven have been handled. The brickwork of the oven suffers somewhat due to abrasion from the load occasioned by its quick movements. No attempt has been made to motorize the withdrawing operation, because only a sharp pull is necessary. One attendant operates the equipment, assisted by the necessary people to load and unload and to pull the hook for quenching.

"LAB-TYP"



CONTROLLED ATMOSPHERES

In Your Laboratory

"LAB-TYP" HEAT TREATING ATMOSPHERE FURNACES fill the need for standard laboratory equipment for appraising the effects of various atmospheres on metals at elevated temperatures—for small quantity work.

RETORT

Gas tight retort measures $4\frac{1}{2}$ " inside diameter with working space 6" deep. Retort atmosphere is entirely separated from furnace chamber. Temperatures inside retort are obtainable up to 1825° F.

FURNACE

Furnace unit is complete with built-in transformer, relay, and thermocouple. Can be supplied with either manual or automatic control. Can also be used as pot furnace for salt or lead bath tempering and annealing.

Ask for Bulletin LT-45

BODER

SCIENTIFIC COMPANY
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ACCOLOY
Heat and Corrosion Resistant
and Stainless Steel Castings

"Team Melting" means better Castings for You . . .

Flexibility of melting equipment, particularly "Team Melting" under close metallurgical control, is our answer to the problem of getting maximum metallurgical quality, improved shock resistance, high fatigue resistance, and better surface stability.

We can combine acid and basic practice, melt ingredients separately for transfer to one furnace, or for combination in the ladle. Our two-ton, three-phase furnace can be operated as either direct or indirect arc, and can hold metal without carbon pick-up.

Uniformity of structure in irregular sections is controlled through chilling and insulating mold surfaces, combined with pressure casting and gas evacuation. Specially designed temperature controlled ladles are one of many advanced features in this unusual plant.

We maintain a special engineering service to help you with your alloy problems. Contact your nearest ACCOLOY engineer.

We'll see you at the National Metal Congress and Exposition, the week of February 4. Look for us in Booth C 117, in the Main Arena, Cleveland Public Auditorium.

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"MP-10"



Model "J"

• UNIVERSAL • BRINELL • PORTABLE Testing Machines

"MP-10" UNIVERSAL testing machine, designed for the making of tensile, transverse and compression tests up to 60,000 pounds, is hydraulically operated . . . A maximum stroke of six inches is provided in the cylinder . . . the transverse table has a maximum span of thirty inches . . . Illustration shows machine set up for tensile test . . . Model "J" BRINELL testing machine, of the manually operated bench type for the hardness checking of metals, is particularly designed to meet the requirements of the smaller

Type "P"



shops, heat treat plants, laboratories, schools, etc. The Multi-Beam and Dead Weight principle is employed, with weights accurately calibrated for loads of 500 kgs. to 3,000 kgs. . . Type "P" PORTABLE Hardness Testing Hammer makes practical the taking of tests right where the material is, in the shop, yard . . . on the truck, car . . . anywhere it may be, instead of taking the specimen to the testing machine . . . There are other standard models and special purpose machines also built to specifications. Send for catalog and complete information outlining your testing requirements.

At the Metals Show . . . space B-720
. . . February 4th through 8th

STEEL CITY TESTING LABORATORY

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Detroit 4, Michigan

Wear Resistance*


NO EXACT physical unit has been found to express hardness, and engineers are still confined to the use of the comparative figures. Most hardness tests attempt to measure resistance to penetration; usually the depth or shape of the deformation is determined. In such methods both the elastic deformation and the tendency to work harden of the metal being tested must be considered. Some methods such as the scleroscope avoid work hardening, but the rebound method seems to depend largely on the elasticity of the surface struck. Dynamic hardness testing appears to be fundamentally different from static hardness testing. Attempts to correlate the hardness values obtained by the various methods are valid only when applied to one type of material under constant testing conditions.

The present methods of measuring hardness seem to be too coarse when compared to the fine structure of the metals to be measured. The question arises therefore as to the properties which it is desired to ascertain when the hardness is measured. Usually, the resistance to penetration or the susceptibility to work hardening is not of interest. The true object seems to be to obtain an indication of the resistance to wear in service. Obviously, neither Brinell, Vickers, Rockwell nor scleroscope values bear any direct relation to the wear resistance. The ideal method would be to make laboratory wear tests. While such tests give valuable information, the present ones are far too complicated for routine work. Scratch tests may give results of practical value under proper conditions.

Recent German studies have given interesting information on the relation between the scratch hardness and wear resistance. Their tests on the rare and heavy metals, as well as sintered carbide, indicate that the scratch hardness and wear resistance (when rubbed against an abrasive) correspond fairly well, but bear little relation to the Vickers hardness values. Sintered carbide had the highest wear resistance while osmium was next. Additional tests on iron-carbon alloys with up to 5% car-

*Abstracted from "Hardness and Wear Resistance", by Martin Littmann, *Engineering*, June 29, 1945, p. 502.

tion, osmium-rhenium alloys and osmium-platinum alloys also showed the sintered carbide to have the highest wear resistance. There was a general correlation between the wear resistance and the modulus of elasticity of elements No. 73 to 79 and 41 to 47. Osmium had the highest wear resistance and modulus.

Therefore, it might be best to rely on scratch hardness rather than indentation or scleroscope methods if wear resistance is important. The relation between wear resistance and scratch hardness, when high pressures are involved or when chemically active lubricants are present, requires further investigation. 

Stress Corrosion Cracking*

CAUSTIC embrittlement and the cracking of steel in hot nitrate solutions are commonly considered as stress corrosion phenomena. Since none of the present theories satisfactorily account for the observed facts, since they offer very little explanation for the intercrystalline propagation of cracks, a new general theory has been developed.

This new theory states that the rate and direction of growth of the crack depend upon the localized electrochemical condition induced by the mechanical forces. After a minute crack has been formed, the stresses at the apex of the crack due to stress concentration accelerate the precipitation of the supersaturating solid phase. Then the corroding solution dissolves the more anodic of the two product phases. This galvanic effect may be possible only in those electrolytes which are moderately corrosive to steel where the matrix probably acquires a noble film.

Stress corrosion cracking of mild steel in nitrate solutions is shown to depend upon the fact that stress accelerates the age hardening of the metal. An excellent correlation has been found between the cracking time and the percentage change of the notch impact values. Both the extent of aging (as measured by the percentage change of the notch impact values) after a standard treatment and the rate of cracking after several heat treatments were correlated with a

(Continued on page 214)

*Abstracted from "Theory of Stress Corrosion Cracking of Mild Steel in Nitrate Solutions", by J. T. Waber, H. J. McDonald and B. Longtin, Electrochemical Society, Preprint 87-32, p. 439.

TRIAD PR Cuts Spray Booth Clean-Up Time

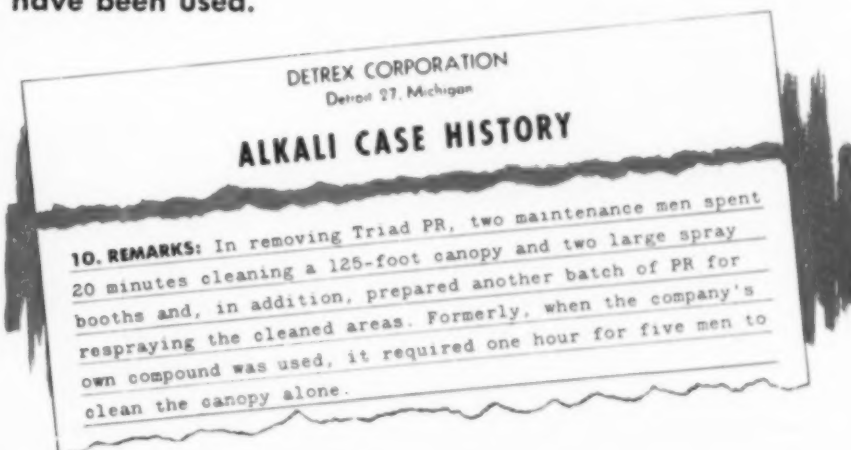
Clean-up time is reduced from hours to minutes when Triad PR is used on the



White, non-glare coating of Triad PR improves visibility in the booth.

sidewalls of wet or dry paint spray booths. Readily applied with a brush or spray gun, PR is quickly removed by water or steam along with all accumulated surface deposits.

Detrex field representatives can also supply scientifically compounded water conditioners to fit your individual wet spray booth set-up. Case histories, compiled by our representatives, have shown that PR and associated Triad spray booth compounds have cut "down-time" and maintenance costs in every installation in which they have been used.



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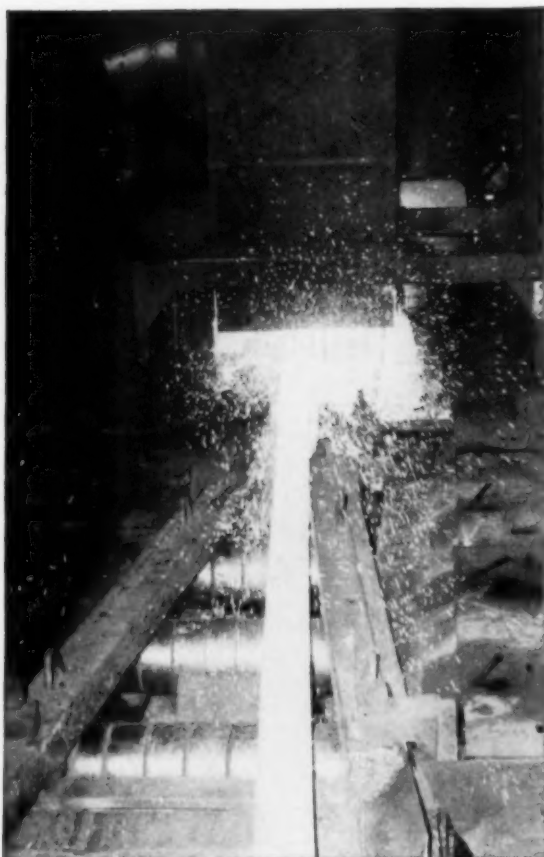
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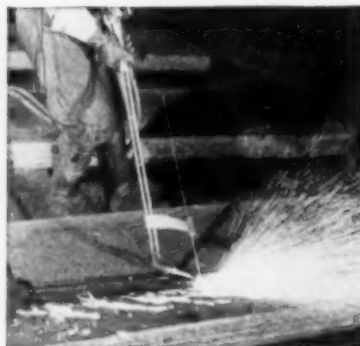
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In steel mills, foundries, and metal fabricating shops Linde's oxy-acetylene methods are among today's most efficient mass-production tools. Machines and supplies required for any of these modern metalworking methods . . . plus specialized engineering help . . . are available from Linde. Ask any Linde man for more information.

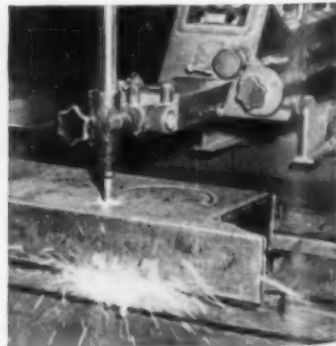
Ingot-Slitting with an OXWELD C-45, the largest commercial blowpipe in the world, makes slicing through this ingot as easy as it looks. This oxy-acetylene equipment eliminates the need for massive power-consuming machines that would otherwise be necessary.



Steel-Conditioning—LINDE oxy-acetylene hot-scarfing machines installed directly on the roll tables remove surface defects from slabs, blooms, and billets. Higher yields of quality steel are thus obtained faster and without interruption of production.



Deseaming—For secondary steel-conditioning or where mechanized conditioning is not practical, Linde's manually operated scarfing equipment is quick, economical, and effective.



Metal-Shaping—For rapid cutting of simple or intricate shapes, straight-lines, or circles, and for plate-edge preparation on metals of any thickness, a complete line of OXWELD machines is available.

DIECASTING DIGEST

X—Pre-Fill Injection, Solid Frame and Large Positive Central Die Support Are Features of New Die Casting Machine

A new, larger and more powerful cold chamber die casting machine for the production of aluminum, magnesium and copper alloy die castings has been developed by Lester-Phoenix, Inc. of Cleveland. Known as the Model HP-3½-X-SF, the new machine embodies the following features:

1. Pre-Fill injection system applies pressure up to 33,000 p. s. i. on die cavities up to 40 square inches in projected area, the pressure being applied instantaneously and held on the metal as it chills in the die. This is known as the *Slow Squeeze* injection method.

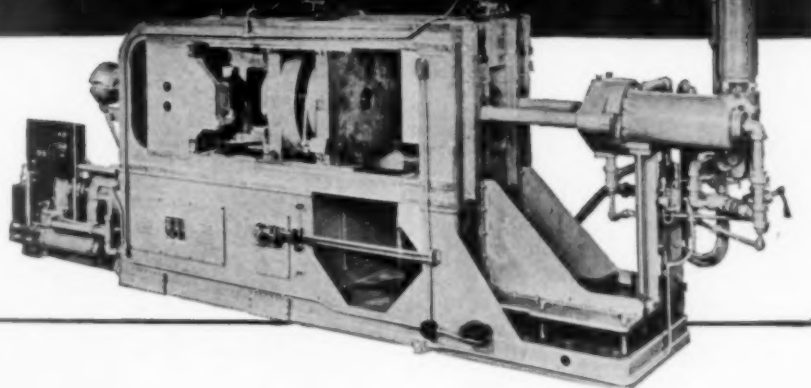
2. Machine frame is a one-piece steel

casting, conservatively rated at 600 tons die locking pressure. Its increased weight and strength is indicated by its cross sectional area of 240 square inches, equivalent to four 8¼-inch tie bars. Toggle linkage within the frame has been simplified and strengthened. Die movement and die space have been increased 60 percent.

3. The central die support has been increased in size, the die plate has bearing on all four corners, eliminating all possibility of deflection of the movable die plate. Rapid, easy die-height adjustment is accomplished by means of a single hand crank through worm and worm wheel rotation of the large adjusting screw.

This construction, along with many other time-tested Lester engineering features, assures the die caster of strong, sound castings, relatively free of porosity and with flash reduced to a negligible factor.

NEW *Heavy Duty* DIE CASTING MACHINE
Produces Large, Sound Aluminum Die Castings at 33,000 p.s.i. Injection Pressure



Aluminum die castings up to 14 pounds can be made on the new Lester-Phoenix HP-3½-X-SF cold chamber die casting machine, with the assurance that the castings will be strong, sound, relatively free of porosity and flash, and have a fine, smooth surface finish. This massive

solid-frame machine, which applies up to 33,000 p.s.i. injection pressure by means of its Pre-Fill injection system, confines that pressure to the die cavities by its conservatively rated 600-ton die locking pressure provided in the one-piece, cast steel frame and in the positive die locking mechanism. Get further details from

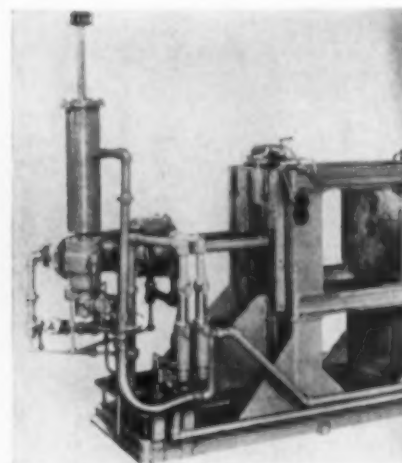
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Would you like to take a look at the entire Lester line of high pressure hydraulic die casting machines? Send for our bulletin.

**Write
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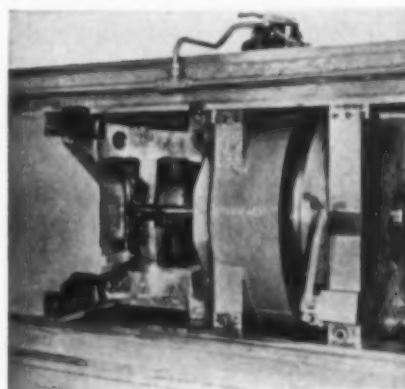
LESTER-PHOENIX
DIE CASTING MACHINES

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Above: Lester Pre-Fill cylinder and standpipe.

Below: Note the positive support to movable die plate from the large adjusting screw.



Pre-Fill Data

Send for the whole story on *Slow Squeeze* injection with the Pre-Fill system. Glad to send you reprints FREE, of authoritative trade magazine articles. Write Lester-Phoenix, Inc., 2619 Church Ave., Cleveland 13, Ohio.





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IT'S THE BEST**

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- TRY IT ON ANY SILVER BRAZING JOB
- IF IT DOESN'T GIVE A BETTER FLUXING PERFORMANCE THAN THE FLUX YOU'RE NOW USING, WE'LL SEND YOU A \$3.50 NECKTIE!



HERE'S WHY THIS FLUX IS ACTUALLY REVOLUTIONARY:

At 480° F NU-BRAZE WONDER-FLUX NO. 4 starts to melt. Because of the extremely low melting point, this flux cleans and lines the joint well before the brazing alloy melts.

At 800° F this faster-acting flux is water-thin and so free-flowing that the molten brazing alloy eases it out of the joint completely.

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Don't take our word—prove it yourself—or you get a \$3.50 tie. Fill in and send this coupon today—Enclose 10c coin or stamps to cover mailing.

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Send me a sample of Nu-Braze Wonder-Flux No. 4. If it doesn't fill the bill, I'll send back the unused portion, and that necktie better be good!

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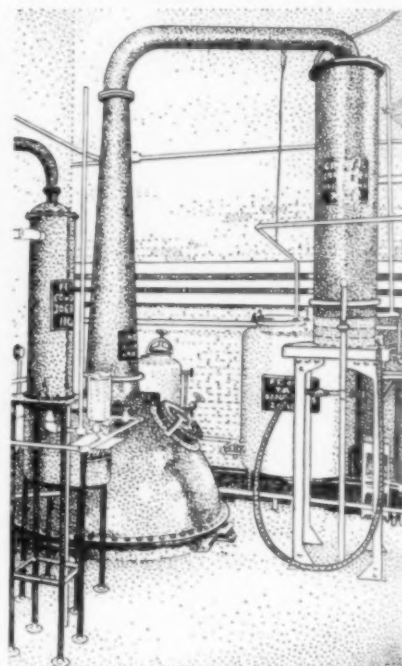
See NU-BRAZE WONDER-FLUX NO. 4 demonstrated at the SHERMAN & COMPANY exhibit, booth No. B-315, at the Metal Show, Cleveland, February 4th to 8th.

Stress Corrosion Cracking

(Continued from page 203)

free nitrogen factor ($2N + P - Al$). Variation in heat treatment caused a parallel shift in the lines of the above correlation.

This concept of "free" nitrogen unifies much previous data on the supposedly independent effects of carbon, nitrogen, phosphorus, oxygen and aluminum. Because the correlation plot is linear, extrapolation indicates that a steel can be made only relatively more resistant—to stress corrosion cracking. For example, the investigators were able to crack repeatedly mild steel that was supposedly resistant. Path of



the cracks was intercrystalline in all the tests.

A satisfactory experimental procedure was evolved, using loaded channel-shaped specimens in a mixture of calcium and ammonium nitrates at 230° F. Cracking proceeded rapidly when steels were loaded to stresses slightly less than the yield point but greater than a certain threshold stress. This stress appeared to be dependent upon the metallurgical condition of the steel. Acceleration of quench aging of mild steel by elastic stresses was also shown, and the age hardening mechanism of stress corrosion cracking was partially confirmed. Finally, the conditions under which cracking occurs do not differ in principle from those necessary to produce caustic embrittlement. ☉